Tasmania

DEPARTMENT OF MINES

GEOLOGICAL SURVEY BULLETIN

No. 8

The Ore-Bodies of the Zeehan Field

BY

W. H. TWELVETREES, Government Geologist

and

L. KEITH WARD, B.A., B.E., Assistant Government Geologist

A Supplement (containing Geological Map and Mine Plans) to this Report is issued under separate cover

Issued under the authority of the Hon. A. E. Solomon, Minister for Mines

Hobart
JOHN VAIL, GOVERNMENT PRINTER

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THE ORE-BODIES OF THE ZEEHAN FIELD.*

I.—INTRODUCTION.

THE English companies carrying on operations in the Zeehan field have been unfortunate enough during the last few years to find the shoots of ore which they have been working either tailing out as they were followed down, or becoming poor and unprofitable. This was the case in the Western Mine, in which practically no payable body of ore was found below 300 feet. After carrying on operations for 14 years the company ceased work in 1901, having put in 9 miles of drives, sunk to a depth of 600 feet, raised ore realising over £493,000 gross, and distributed £102,000 in dividends. The mine was refloated in 1903, and with the assistance of the Tasmanian Government the main shaft was continued down to 1000 feet and the lode cut with unsatisfactory results.

The Zeehan-Montana Company, whose mine adjoins the preceding one, started in 1893, has raised over £400,000 worth of ore, distributing dividends to the amount of nearly £133,000. It has opened out eight levels from its main shaft, which is down to 800 feet. Below 400 feet the ore-shoots contract, and the lodes are patchy.

The Queen property has lodes which paid well in the upper levels, but when followed down they became pyritic and barren of galena.

The Spray lode has been worked down to 450 feet by the Mt. Zeehan (Tas.) Company, yielding good dividends, until the shoot became poor and the mine was abandoned. This company has returned somewhere near £170,000 in dividends to its shareholders.

The other mines at Zeehan are mostly shallow ones, and have not been worked to a depth sufficient to admit of any reliable opinion being formed with respect to the behaviour of their lodes at lower horizons. In several cases when the shoots which were being operated fell off in quality or disappeared the necessary funds for further exploration were withheld by investors, and work ceased.

* The chapters on Physiography, Previous Literature, and General and Economic Geology in this report, have been written by Mr. L. K. Ward.

The British companies owning the deeper mines, having met with no success in their bottom workings, seem to have lost heart. The Mt. Zeehan (Tas.), the Zeehan-Queen, and Zeehan-Western have suspended operations at Zeehan. The Zeehan-Montana Company, judging from the utterances of its chairman in London, shares this despondent feeling, and seems prepared to relinquish deeper trial, as he emphatically maintains that sinking to greater depths in Zeehan has now been conclusively proved to be practically waste of money. This statement has, however, only a very narrow and precarious base, being founded on the work accomplished in the lower workings of the two deep mines; but coming from such a source, it is, if not refuted, calculated to injure the prospects of the field.

Under these circumstances the Government of Tasmania authorised a geological examination of the field in order to enable a sound opinion to be formed with regard to the downward continuation and permanence of the lodes.

We have spent three months in the district endeavouring to acquire all available information bearing upon the subjects dealt with in the present report. The aim has been to present the results in a concise and readable form. It has, moreover, been sought to make the report as comprehensive as possible, and to probe theoretical questions fully, so as to cover all matters which can in any way be of use to the professional advisers whose advice may be taken by mining companies in connection with their future operations.

Unfortunately very few of the deeper and more important mines were at work, and the workings of many shallow mines were also inaccessible. Consequently during the examination of the district we continually felt ourselves at a disadvantage. Our conclusions in some instances are, we feel, not based upon such strong evidence as we should have liked to obtain, but are the best possible under the circumstances.

Although it has not been our intention to supply descriptive reports of mine workings, general remarks are made on such mines as were accessible. In doing this, care has been taken not to encroach upon the province of the mining engineer.

Owing to the operation of block faulting to a considerable extent, and subsequent denudation, the elucidation of the general geology and physiography of the field is attended with extreme difficulty. To arrive at a complete explanation would require more time than we were able to devote to these questions. They have, however, been discussed generally and comprehensively, and at any rate sufficiently to indicate the nature of the problems involved. Moreover, the discussion suggests in which direction the solution of the difficulties may lie.

II.—HISTORY OF THE FIELD.

The rapid progress of the West Coast is forcibly impressed upon the mind by remembering that less than 30 years ago the town of Zeehan had no existence. Frank Long and John Healy, in 1882, made their way through to Mt. Zeehan from Long Plains, and penetrated the dense inhospitable bush as far as the site of the present town. Here, on the 8th December in that year, Long discovered a galena lode, and pegged a section for the association for which he was exploring—the Arthur and Long Plains Prospecting Association. The market value of lead was very low at that time. Several sections were taken up, but the serious attention of investors could not be attracted, and matters remained quiet until the Broken Hill discoveries and improved metal prices led to a revival of interest in the field.

In 1887 a lode was found on the Silver Queen property, and after some years' prospecting sinking was begun by that company in 1890. The Silver Queen Company may be said to have been the first to engage in work on a large scale, and we believe it was the first to declare dividends. In a few years numerous companies were at work; among these were Balstrup's Manganese Hill and Central, Despatch, Grubb's, Junction, Mt. Zeehan (Tas.), Mt. Zeehan, Silver Bell, Silver King, Western, &c. In 1891 mining was extremely active, and the mining market excited over repeated fresh discoveries, but in August of that year the suspension of the Bank of Van Diemen's Land caused a sudden financial collapse, from which the field took some time to recover. The intrinsic resources of the field, however, eventually caused a resumption of mining on a larger scale, and this has resulted in a continuous output of mineral up to the present day.

Among the mines which in the last decade have been the most prominent ore-producers are the Mt. Zeehan, Zeehan-Montana-Western, Oonah, Silver Queen, &c. These have returned large dividends to their shareholders. But after working steadily on their lodes down to about 300 feet from surface, the large lead-mining companies found that the shoots of ore upon which they were operating tailed out or began to be unremunerative below that level. Some of them continuing work a little further down, and finding the lodes still unpayable, suspended operations; *e.g.*, Western, Queen, Oonah Lead, Spray, King, &c. The

THE TASMANIAN SMELTING COMPANY'S WORKS

Zeehan-Montana alone kept on producing ore under difficulties, but also continuously exploring without substantial results.

The net result is that the output of ore from the Zeehan mines has shrunk to an annual value of about £100,000. So few companies have been deep mining and working regularly that the impoverishment of a few shoots simultaneously, while too inadequate a factor to have any real bearing upon the question of permanence of ore-deposition, is still sufficient to produce temporarily a serious effect on the prosperity of the field.

About 1889-90 was the date when a first attempt (unsuccessful) was made by private capitalists (Col. Smith, of Ballarat, and others) to get a tramway through to Zeehan from Strahan. In 1890 the Tasmanian Government undertook the construction of the 28½ miles of 3 ft. 6 in. railway to connect Zeehan with the port in Macquarie Harbour. This line was opened in 1892, and has been running successfully ever since. The Emu Bay Railway Company's line of the same gauge also connects Zeehan with Burnie, the port in Bass Straits. The N.E. Dundas 2 ft. line, too, runs out of Zeehan to Williamsford, at the foot of Mt. Read. It was opened for traffic in 1898. There is a line also to Dundas and Maestries.

Prior to these railways the only communication with Zeehan was by way of Trial Harbour, where there is only a narrow channel between two reefs, covered at high water. Coastal vessels were not always able to venture in. Zeehan is about 12 miles from Trial, now deserted, and the time when £5 per ton had to be paid for transport between the two places is now looked back upon as ancient history.

The furnaces of the Tasmanian Smelting Company, erected in 1898 on the Zeehan-Strahan railway-line, 2 miles from Zeehan, at present serve the field. The company has received assistance from the Tasmanian Government in the form of a loan to the amount of £20,000, besides large concessions in the way of ore freights. The ore sold to it from the Zeehan field, however, has been insufficient for continuous work, and the company has been unsuccessful in its negotiations for the purchase of ores from the surrounding districts. Hence its operations have of late been intermittent. When the furnaces are in full blast the smelting enterprise contributes to the support of a considerable proportion of the population of Zeehan, but any serious curtailment of operations produces undesirable dislocations in the mining industry of the district. It is also freely stated on the field that the need exists for a better adjustment of smelting charges to the requirements of profitable mining. On the other hand, the Smelting Company looks to the safeguarding of its own interests. In any case, the present position is not an ideal one.

III.—PREVIOUS LITERATURE ON THE ZEEHAN FIELD.

The following list comprises the titles of the official publications on the Zeehan field and neighbourhood issued by the Tasmanian Government:—

(1) Western Mining Districts, June, 1884, by Mr. G. Thureau.

(2) Report on the Silver-lead Deposits near Mt. Zeehan, Montagu County, West Coast of Tasmania, April, 1885, by Mr. G. Thureau.

(3) Report on the Mt. Zeehan Silver-lead Lodes and other Deposits, March, 1888, by Mr. G. Thureau.

(4) Progress Report on the Mt. Zeehan Silver and Argentiferous Lead Lodes, and other Ore-deposits, December, 1888, by Mr. G. Thureau.

(5) Report on the State of the Mining Industry on the West Coast, April, 1890, by Mr. A. Montgomery.

(6) Report on the Progress of the Mt. Zeehan and Mt. Dundas Silver-lead Fields, November, 1890, by Mr. A. Montgomery.

(7) Interim Report on the State of the Mining Industry on the West Coast, April, 1893, by Mr. A. Montgomery.

(8) Report on the Progress of the Mineral Fields of the County of Montagu, May, 1893, by Mr. A. Montgomery.

(9) Report on the Progress of the Mineral Fields in the Neighbourhood of Zeehan, May, 1895, by Mr. A. Montgomery.

(10) Report on the Zeehan-Dundas Mineral Fields, February, 1896, by Mr. A. Montgomery.

(11) Report on the Mineral Districts of Zeehan and Neighbourhood, October, 1900, by Mr. W. H. Twelvetrees.

(12) Report on the Western Silver Mine, Zeehan, September, 1902, by Mr. G. A. Waller.

(13) Report on the Tin-ore Deposits of Mt. Heemskirk, September, 1902, by Mr. G. A. Waller.

(14) Report on the Iron and Zinc-lead Ore-deposits of the Comstock District, February, 1903, by Mr. G. A. Waller.

(15) Report on the Zeehan Silver-lead Mining Field, April, 1904, by Mr. G. A. Waller.

Of these publications, that which deals in fullest detail with the geology of the district is the one which was prepared in 1904 by Mr. Waller. With it a contoured geological map and a geological section were published.

To this report reference should be made for an account of the several mines the workings of which were inaccessible at the time of our visit.

IV.—PHYSIOGRAPHY.

The topography of the Zeehan district is exceedingly complex in character, and correspondingly difficult of interpretation. There are many apparently contradictory phenomena to be observed, the explanation of which will be more readily appreciated when a systematic survey of the whole outlying area has been achieved and reduced to map form. The central portion of the Zeehan field itself has been topographically mapped by Mr. G. A. Waller, formerly of the Geological Survey of Tasmania, and his map has proved of inestimable service to the mining community. During our investigation of the district we have made constant appeal to the contoured map which he prepared, and a great economy of time has resulted from its existence.

The mining area of Zeehan is one of marked relief, where a number of dissected ridges occupy a position intermediate between the mountain range of Mts. Agnew and Heemskirk on the west, and the broad, relatively low-lying area drained by the upper branches of the Little Henty River on the east.

The western portion of the Zeehan field reaches its highest point at the Oonah Hill, through which passes the divide between the watersheds of the Pieman and Little Henty Rivers. The Oonah Hill itself stands in relief as the highest remaining point of a region which at one time attained a very much greater altitude.

In order that the present topography may be appreciated the principal factors in its evolution must be briefly considered.

The study of the geological history of Western Tasmania has led to a belief in the operation of at least two great cycles of denudation. One of these is extremely ancient, having followed immediately upon the Devonian irruptions of acidic and basic material. The extent to which the denudation of this period lowered the surface is not known, and the contours developed at the end of the period cannot be ascertained. However, from the fact that the lowest members of the next succeeding sedimentary series (Permo-Carboniferous) contain fragments of the granite itself, it is evident that the surface was so deeply dissected that the plutonic rocks of Devonian age were already exposed to surface agencies at the beginning of the Permo-Carboniferous period. The Heemskirk *massif* almost certainly has been one of the exposed sources of the granitic boulders.

The advance of the Permo-Carboniferous sea afforded protection to this denuded surface, which was probably covered by the deposits then laid down and by the succeeding deposits, until perhaps the whole of any granite outcrop was once more covered.

The Upper Mesozoic diabase is represented to the north-east of Mt. Heemskirk*, but it is not now certain what was the former extent of the rock in this district.

Since the close of the Mesozoic era the whole region has shared in the degradation which has been in progress throughout the island. This long cycle of erosion, which is still operative at the present day, has apparently at one stage of its development achieved the peneplanation of considerable portions of the western coastal regions. And during the periods in which the work of denudation has been in progress almost all the post-Devonian rocks have been removed. In addition to the diabase mentioned above, there are shallow and isolated residual fragments of the glacial beds which probably represent the basal members of the Permo-Carboniferous series.

Thus the present surface represents the sum total of the destructive effects of two long periods of denudation, separated by a very long period (from the beginning of Permo-Carboniferous time to the close of the Mesozoic era), during which the only known remaining records show that constructive agencies were at work. By reason of the long continuation of the later cycle, the details of the former have been obliterated, and the stage of maturity attained by it cannot be ascertained.

With regard to the later cycle of erosion, however, there is more available information, since certain remaining land forms give evidences of the physiographical history.

There has been at least one period of persistent relative stability between land and sea, during which the sculpturing of the land has attained a mature stage of development, and a peneplain of considerable extent has been produced. By a negative movement of the strand-line this peneplain has been dissected, and only by its remnants can it be recognised. Perhaps the best view of part of the peneplain may be obtained from the heights of Mt. Agnew, whence the general equality of height of its western portion may be observed. The peneplain forms a

* See G. A. Waller, "Report on the Tin Ore Deposits of Mt. Heemskirk," 1902, p. 2.

coastal belt and runs back to the base of Mt. Zeehan, and its dissected remnants lie between Mt. Heemskirk and the sea. The Little Henty River near its mouth, and the smaller streams which flow westward and enter the sea at different points along the coast, have carved deep gorges in the surface of the peneplain, so that the original general equality of altitude can only be observed from a higher elevation.

The eastern border of this coastal plain stretches back to the south-western portion of the mapped area of the Zeehan field, and there has an altitude of about 700 feet above present sea-level. The land-forms of the eastern portion of the Zeehan field which should be correlated with this dissected surface are at first sight difficult to recognise, since they are now so modified by the later erosion. These appear to be the low hills and ridges which lie on both the northern and southern sides of the Zeehan township, the crests of which rise to a height of about 750 feet above sea-level.

The King Extended Hill, and the hills between Zeehan and the Austral Valley, are the nearest to the township, and the hill upon which the smelters are built probably belongs with these to the same physiographical unit.

It is of interest to compare with these altitudes the only other available data with regard to the West Coast region. In the northern portion of the tinfield of North Dundas an old peneplaned surface has been recognised.* It is now deeply dissected to varying depths by the Pieman River and its tributaries, but the remnants of the peneplain are all at the same level, and about 700 feet above present sea-level.

It is not possible to draw other close comparisons between the Pieman peneplain and that of the Little Henty. In the former the distribution of certain sediments coincides with the surface of the peneplain, and lends support to the historical inferences based upon topographical features. But in the Zeehan district there is no such deposit of sedimentary material that the geological character will assist in developing the physiographical history.

If we may be justified in correlating the Little Henty peneplain with that of the Pieman, and in regarding the two as having been contemporaneous, the period of physiographical maturity of which the peneplains are the witnesses was attained at or about the time of the Pleistocene

* Geol. Surv. Tas., Bulletin No. 6: "The Tin Field of North Dundas" 1909 pp., 6–9.

glaciation. But further information is required before the correlation can be regarded as based upon firm ground.

Another matter of some importance will follow if the two peneplains can be closely compared. The facts already known with regard to the present height of the peneplaned surfaces above sea-level show a remarkable uniformity in the two regions. From these it would appear that the crustal deformation which has revived the river systems and started the dissection of the peneplains has caused a simple negative movement of the strand-line such that a considerable area remained at an approximately equal height above sea-level.

When the old peneplain of the Little Henty River is examined it is at once seen that the dissection of the eastern portion (in Zeehan) is strikingly dissimilar from that of the western (on the sea-coast).

While in Zeehan the valleys are shallow, broad, flat-bottomed, and singularly uninterrupted by spurs; on the coast the valleys are deeper, and in all other respects dissimilar from the easterly ones. As instances, the characteristics of the different branches of Parting Creek and those of the lower part of the Little Henty River may be contrasted. The essential differences between the two areas are caused by the differences in the amount of the deepening of the stream-beds. On the west the outlet of the streams has been towards the sea, and the effect of the progress of erosion is shown principally by the deepening of the valleys, in the effort of these streams to cut down their channels to base-level. The outlet being free towards the sea, the whole extent of the strand displacement has been effective. On the east the outlet of the streams of Zeehan has been towards the upper branches of the Little Henty River. The depths to which the different contributory streams have been able to cut down their channels have been dependent upon the progress of a similar action in the main stream. Now the upper part of the Little Henty River finds a way to the sea through the gap which it has carved down between the south-eastern spur of Mt. Zeehan and Mt. Professor. When the dissection of the whole peneplain was begun by a relative uplift of the region above sea-level the grading of the Little Henty as a whole has doubtless been delayed by the necessity for the deepening of the gap (which already existed) through the hard West Coast Range conglomerate of which Mts. Zeehan and Professor are constituted. The upper branches, therefore, of the Little Henty River have deepened their channels slowly, and the streams which flow into these have also very gradually worn down their several valleys. The result is that the contributory streams are characterised by valleys which are broad in proportion to their depth, and well graded. But they are almost entirely free from any deposits of rock waste, for as fast as each contributory stream has graded, or nearly graded, its valley, it has been revived by a further deepening of the bed of the larger stream into which it flows. So the upper portion of the Little Henty River system presents features of greater maturity than does the lower, and the principal controlling influence causing these phenomena is the West Coast Range conglomerate belt through which the river passes.

Above the old peneplain of the Little Henty River there stood out in relief the principal higher ridges and peaks, which have suffered continuous denudation right up to the present day. The Oonah Hill, the ridge running from the Spray Mine through the Nubeena and South Nubeena sections towards Mt. Zeehan, Mt. Zeehan itself, and the Heemskirk Range, all stood above the level of the old peneplain, and are probably even more prominent at the present day. Of these the Heemskirk Range and Mt. Zeehan are far the highest, and to them the dignity of the name of "mountains" cannot be denied. Their altitude is without doubt due to the superior resistance of the rocks whereof they are composed. For the Heemskirk granite and the West Coast Range conglomerate are the two most resistant rock-types developed in the whole region.

How far the physical characters of the rocks have influenced topographic development in the rest of the district is not quite certain. The Austral Valley and the Argent Flat coincide almost exactly with two arms of a single lithological division (slates, keratophyric tuffs, and breccias),* but the same rocks form the crest of Manganese Hill, and extend westwards along the high country towards the Comstock district. It is possible that at the present time the valley erosion has not proceeded sufficiently far for this higher ground to be removed, although the tendency is really displayed by the carving of the lower ends of the valleys. The presence of Silurian limestone has certainly predisposed some areas to greater relative denudation. The flat ground between the Smelters-road and the railway-line, and in the Despatch and Austral Valleys, doubtless owes its lack of relief to this limestone. In other cases

* *Vide infra*, p. 18.

there is no apparent coincidence between lithological character and topographic form.

The influence of the topographic features upon mining has not been very great in Zeehan itself. In very few cases are the lodes so situated that adits could give any considerable depth of backs. Hence adit-mining has been practically restricted to the Spray and Nubeena Hills.

Since the whole area is an elevated one which has been undergoing denudation, and since the ore-bodies are not such that they can withstand weathering agencies with greater success than the country-rocks which contain them, the majority of lodes have shared in the general degradation of the region, and the unoxidized ores occur at the very surface. This matter is referred to at some length in a later part of this report.*

* *Vide infra*, p. 76 *et seq.*

V.—GENERAL GEOLOGY.

(1)—The Igneous Rocks.

A.—SPILITE.

This rock is that which has long been referred to as the melaphyre of the Zeehan field. Both massive and fragmental developments of it are known. In the massive form it is an amygdaloidal, dense-grained, and greenish-grey rock, with a dull or earthy lustre on freshly-broken surfaces. It is often traversed by narrow veinlets, some filled with dark-green chlorite, others with calcite.

The rock is commonly vesicular to a marked degree, and the vesicles are always filled. The amygdules are usually dark-green to black in colour, but are occasionally white. In size they range from that of a pin's head up to half an inch along the longest diameter, and usually are between one-twentieth and one-tenth of an inch in diameter. A little disseminated pyrites is sometimes visible, but this is probably a secondary impregnation. At other times the rock is indurated by silicification, and breaks then with a conchoidal fracture.

The structure of the fine-grained groundmass of the rock cannot be ascertained with the unaided eye. In a few cases it is possible to detect the presence of minute crystals of pale-grey colour, but not to ascertain their character. The rock possesses a characteristic white streak.

When thin sections are examined under the microscope the most striking textural feature is the absence of crystals of any magnitude. The groundmass is difficult to determine, but it has doubtless been to some extent vitreous. It is crowded with microliths of felspars, many of which are curved and imperfectly developed. Some of these microliths appear to be untwinned, while in others simple and multiple twinning may be detected. In the case of those which show distinct multiple twinning, the extinction angles measured from the twin lamellæ are in the majority of instances very small, but rise in some crystals as high as 20°. In the case of the smaller microliths, which do not exhibit visible twinning, the extinction angles are always small.

Occasional quartz granules are discernible. Their outlines are irregular and anhedral, for the crystals have apparently been partly resorbed in the magma. These are sporadically distributed through the rock. There is no regular parallel arrangement of any of the component crystals or microlites, and signs of flow-structure are rare.

Grains of iron ore (ilmenite ?) are scattered through the groundmass and tend to collect round the margins of the vesicles.

The numerous amygdules which were primarily steam-pores are sometimes elongated, but more frequently are approximately spheroidal in form. In some cases the amygdules are composed of one mineral only, but more often they are composite. The mineral material which fills them is usually chlorite or calcite, and occasionally quartz or some lime zeolite is present. The structure is variable, the component minerals being sometimes arranged in concentric layers with radial orientation, sometimes in granular aggregates, or again at times in spherulitic aggregates.

The chlorite is difficult of determination. In all observed cases the centripetal fibres have positive elongation. Much of it is colourless in thin section. Some of it polarizes with a dark-indigo tint, suggestive of penninite; in many of the vesicles the radial concentric structure is characteristic of delessite.

In one thin section are visible a number of aggregates of quartz granules, felspar microliths, and chlorite, which resemble phenocrysts. Their exact nature is difficult to discern. On the one hand they suggest the former presence of felspar crystals, but on the other hand offer a still closer resemblance to the glomero-porphyritic aggregates found in some effusive rocks.

A determination of the silica percentage in an apparently typical specimen from the Montana Mine afforded the surprisingly low figure of 42·4 per cent.

The Zeehan spilite is closely comparable with the " lime diabase " of Sechshelden bei Dillenburg, Nassau.

The foregoing description is applicable to the massive developments of the rock. There are, in addition to these, considerable masses of breccias and tuffs of varying degrees of coarseness. The greater part of the angular fragments constituting these clastic varieties of the rock are disintegrated portions of the massive rock described above.

In thin section the pyroclastic origin of these rocks is also very apparent. They differ from the massive forms in the relatively greater abundance of quartz and felspar, which, however, appear to be of secondary origin. Tenuous films of a sericitic mica are disposed among the secondary minerals.

Fragments of the vesicular spilite form the greater part of these rocks, and are of very irregular shapes. The vesicles have in many cases collapsed, and on this account appear more irregular in form than those in the massive rock. In the finer-grained varieties traces of a wavy banding cross the rock, with a more or less constant direction.

The vesicles are filled with glassy matter, zeolites, and often with quartz spherulites. The interstices between the fragments are usually filled with spherulitic aggregates of quartz, divergent fans of felspar (albite), chlorite, and calcite.

It appears to the writers that it would be better if the mining community accustomed themselves to recognise this rock-type by the name of "spilite." Hitherto, with some indifference to etymology, the rock has been referred to as either "melaphyre" or "white rock."* The latter should certainly be abandoned forthwith, since it may lead to confusion with the paler-coloured members of the sedimentary series.

The absence of larger crystals (phenocrysts)† is characteristic of spilite, a name which in France and Germany has been applied to forms of amygdaloidal diabase and melaphyre, in which porphyritic structure is absent. These are the lime-diabases of the older literature. H. Rosenbusch in his "Ergussgesteine" (1908, p. 1271) says:—"It is to be remarked that the amygdaloidal structure is not of determinative value: amygdules occur in all effusive rocks, and now and again they are quite subordinate or absent in spilite. The special characteristic of this group consists rather in the retreat of the intratelluric crystals, and in the abundance of those belonging to the period of effusion."

There can be no doubt whatever but that the majority of the masses of spilite constitute consolidated outpourings of lava, which has been rendered vesicular by the expansion of the imprisoned vapours under conditions of diminished pressure. There appear to be also intrusive dykes of exactly identical material, one of which may be seen in the face of the slate cutting near the Zeehan-Montana Mine office. The vesicular texture is not commonly

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* Among the miners the presence of the numerous dark-coloured amygdules has led to yet another name—"bile bean rock."

† Phenocrysts are the larger porphyritic crystals enclosed in the general groundmass of a rock, and considered as crystals formed prior to the emission of the lava (during the *intratelluric* period of Rosenbusch).

developed in dykes, but since it is due to diminution of pressure, and not to the form of the conduit for the molten material, such a texture may occur in the upper portions of any dyke, provided that the rising igneous material is charged with the necessary vapours.*

The fragmental varieties of the rock are, of course, entirely effusive facies.

Both the clastic and massive forms occur interbedded with normal aqueous sediments, in such a manner that it appears quite certain that the eruption has been a submarine one.

The area over which the spilites and their tuffs and breccias are now found distributed is not a very large one. The principal developments occur within the boundaries of the Zeehan Queen, Oonah, Montana, and Western mines. A further development occurs on Section 67-93M, a mile and a half north of the Western Mine.

The principal occurrences are therefore for the most part restricted to one of the most developed portions of the Zeehan field. But so complex have been the disturbances in this area, it has been found impossible to record each several sheet or tuff-bed upon the geological map.

B.—THE KERATOPHYRIC TUFFS AND BRECCIAS.

Interbedded with certain of the slates and crystalline sandstones of the field are a series of fragmental rocks, which are certainly of pyroclastic origin.

The coarser varieties or breccias form narrow mottled bands in the dark-green slates. The original appearance is masked to some extent by subsequent crushing, and the surface-weathering adds further difficulties to the recognition of the rock. The coarse bands pass over into others of much finer grain, which appear to differ chiefly in respect of the proportion of sedimentary material present. While the breccias contain crushed fragments of the rocks of the sedimentary series, the tuffs are wholly composed of igneous material. The tuff, on being examined microscopically, is seen to be formed of the shattered fragments of some acidic rock-type. Fragments of complex character—possibly representing portions of the groundmass of the shattered rock—are frequent. They consist of partly devitrified glass, containing felspar laths of small

* See Sir A. Geikie's "Textbook of Geology," Fourth Edition, Vol. II., p. 745.

size. With them are associated angular fragments of crystals—possibly the phenocrysts of the parent rock. The fragments of all kinds are so arranged that their longer axes show a general parallelism. This direction is that of the stratification of the rock, and along the bedding-planes are developed secondary minerals, of which calcite and chlorite are the most abundant. The broken pieces of crystals consist of quartz and plagioclase felspar.

The actual bulk of these tuffs is not very large in the immediate vicinity of Zeehan. They are curiously distributed, being arranged along three main directions, which radiate from a centre at Manganese Hill. One direction extends westwards through the Comstock district, another follows the course of the Argent Flat to the north-north-east, and the third extends down the Austral Valley as far as the Smelters-road. These areas have been delimited by complex faulting, and their original structural features cannot be now determined.

C.—SPHERULITIC ROCK.

There is an isolated occurrence of a spherulitic rock within the boundaries of the Montana Mine, which is mentioned separately because of the difficulty of assigning to it definite affinities. It is so thoroughly silicified that its original nature—if, indeed, it is of a secondary character—is problematical.

Macroscopically, it is somewhat variable in appearance. Some specimens are dull-white or greenish-white, and others have a prevalent reddish tinge. There is a white base, which has the appearance of porcellanite, and in this are set the spherules. The spherules are at times so closely packed that no base appears between them. They are pale-green or blood-red in colour, and in many cases both colours are exhibited by one spherule. The radial structure of the spherules is visible to the naked eye, and their average size lies between one-sixth and one-quarter inch in diameter.

In thin sections the spherules are seen to be cloudy with inclusions, some containing moving bubbles. Their radial nature becomes apparent between crossed nicols. A dark cross then appears, the arms of which do not move with the rotation of the slide, but remain parallel with the vibration-planes of the nicols. At times the cross has double arms. The spherules become deformed when closely packed together, yet they preserve their radial structure.

Their optical character is positive, as would be the case whether they were composed of quartz or microfelsite. In general appearance the material is quite homogeneous, and resembles quartz.

The centre of each spherule is the meeting-place of the radial structures, which are wavy, and have a scaly imbricated appearance.

The margins of the spherules are bordered with a narrow radial fringe of divergent tufts, substantially, but not exclusively, optically continuous with the substance of the spherules. This fringe shades off into a cryptocrystalline groundmass, like that of the felsophyres, in which are some small spherulites of doubtful nature. The marginal fringes sometimes suggest felspathic or quartzo-felspathic material, but the analysis of the rock shows its composition to be almost wholly silica.*

Only one mass of this rock has been found. It was situated in the Montana Flat, near the mine buildings, and has now been broken up and removed, for on account of its handsome appearance when cut and polished the rock attracted no little attention. Some years ago an attempt was made to ascertain whether the mass of this rock was a boulder, or portion of a reef, or other rock *in sitû*. The attempt was not carried far enough to settle the question, but the indications were that it formed part of the solid rock. It is situated in a locality where the immediately adjacent rocks are slate and spilite breccia.

D.—GABBRO-AMPHIBOLITE AND SERPENTINE.

A somewhat variable group of rocks is here briefly considered. The exposures lie to the westward of the area which has received the most detailed examination. Mention of them cannot be entirely omitted, pending further investigation, for the rocks occupy an important place in the geology of the region.

Gabbro-amphibolite.—These rocks have a prevailing dark-green colour, from the predominance of the ferromagnesian constituents, but sometimes in the coarser-

* There seems to be a consensus of opinion among petrologists that the spherules of quartz-porphyries are submicroscopic mixtures or intergrowths of quartz and potash felspar, or in other words are essentially microfelsitic. See discussion of felsospherulites in H. Rosenbusch's "Ergussgesteine," 1908, pp. 801-9; and descriptions and figures of spherulitic structures, J. P. Iddings' "Igneous Rocks," 1909, Vol. I., pp. 228-233.

grained varieties the white or pale-greenish felspathic ingredients become important, and the rock has a mottled appearance.

The ferromagnesian mineral—hornblende—is most frequently in stout blades, which may in the coarsest varieties attain the length of 3 inches. However, radiating fans of a fibrous amphibole are also present, and in some fine-grained varieties are the only mineral recognisable by the unaided eye.

Epidote is occasionally fairly abundant in the coarser-grained kinds.

When microscopically examined the original gabbroid character of the rock is at once apparent, especially in the coarser varieties.

Felspar is abundant in large crystals, which are kaolinised. It is multiply twinned, and the extinction angles measured from the albitic twinning lamellæ are large, indicating labradorite. Round these larger kaolinised crystals there is often a fringe of clear secondary plagioclase, which has the extinction angles of albite.

The amphibole is all rather pale in colour, being tinted bluish-green, green, or yellowish-green. The larger plates are seldom composed of a single crystal, since the orientation is different in different portions, and one part merges into another without any well-defined boundary. In addition to the larger plates, the amphibole is disposed in sheaf-like aggregates or diverging fibres, which are grouped together without admixture with other minerals, or are associated with anhedral epidote and secondary albite.

In the fine-grained varieties the constituent minerals are the same. The principal difference lies in the texture and mode of arrangement of the amphibole. Imperfectly-developed radial aggregates of amphibole crystals are common, and a poikilitic texture is developed by the growth of optically-continuous amphibole about the felspathic material.

These rocks are developed on a large scale in the Western portion of the field, and are exposed at two points along the Trial Harbour-road. Their full extent has not been determined. They are exposed at no great distance from the grantite *massif* of Heemskirk, and at one place approach to within a few chains of it. They are plutonic igneous rocks, which have suffered amphibolitisation.

Serpentine.—Some detached fragments of a silicified serpentine have been found at the surface, near the old Tenth Legion Mine, in the Comstock district. The parent rock is doubtless adjacent. A larger mass at Trial Harbour was not examined in detail.

E.—QUARTZ-MICA-GABBRO.

This rock has at first sight the appearance of a serpentine. Beneath a limonite-stained crust the rock is dark greenish-grey in colour. It breaks with a fracture inclined to be platy, and the feel of the broken surfaces has some suggestion of greasiness.

On close examination with the unaided eye the only recognisable mineral is biotite, which is present in flakes of brown colour.

Thin sections, however, reveal the presence of a number of other minerals. There is abundant felspar, most of which has been much altered. On the one hand it has been kaolinised, and on the other hand sericitised, according as the alteration has been effected by meteoric or by juvenile waters. Much of it has certainly been plagioclase, but exact determination is impossible.

The ferromagnesian minerals are also considerably altered. The sericitisation has effected them also. But in most cases there is a serpentinous material, apparently replacing original pyroxene, and possessing the characteristic net structure which results from such replacement. Traces of the original mineral remain in some cases, and from the fact that both straight and oblique extinctions are observable, we may infer that there were both orthorhombic and monoclinic pyroxenes present in the unaltered rock.

Pegmatitic quartz-felspar intergrowths are present, and quartz is fairly plentiful.

Biotite, also, is not uncommon. It varies in colour from brown to pale-yellow.

The only other constituent is accessory apatite in grains. The rock is far too highly acid for a normal gabbro. It may be termed a quartz-mica-gabbro.

Eichstädt, quoted by Rosenbusch,* places under the name of a mica-gabbro rocks in which biotite more or less takes the place of diallage. In this variety quartz is said to be more plentiful, the plagioclase more acid, orthoclase appears, and quartz-felspar intergrowths occur.

The exposures of this rock are poor. One dyke only is known, and, owing to its proximity to lode-fissures, has

* Mikroskopische Physiographie der Massigen Gesteine, 1907, Part I., p. 348.

suffered such alteration by the mineralising solutions that those portions below the weathered crust are considerably altered at some points. The dyke crosses the Comstock tramway at the eastern end of the Summit cutting.

F.—THE GRANITE OF MOUNT HEEMSKIRK.

The granite *massif* of Mt. Heemskirk has played so important a part in the genesis of the lodes of the Zeehan field that some brief mention of its characteristics is necessary.

It is not a simple homogeneous rock mass, and an account must be given of the principal varieties.

The normal granite which constitutes the greater part of the *massif* has a prevalent reddish hue, due to the colour of the principal felspar—orthoclase.

The grain is medium-coarse, and there is no very marked disparity in size between the component minerals. In addition to the pink orthoclase, but in smaller bulk than it, there are present crystals of pale-greenish plagioclase, while the rest of the rock is composed of quartz and biotite mica, and tourmaline is sometimes visible.

This granite passes over into a paler-coloured variety of finer grain, in which quartz and felspar form the bulk of the rockmass. With them occur larger flakes of black mica, the borders of which are strongly corroded; and sometimes a little tourmaline is visible to the unaided eye. At a number of places this finer-grained variety contains immense numbers of spherical segregations. The core of these is composed of quartz and tourmaline, while between them and the fine-grained granite there is usually a quartzo-felspathic admixture, which contains a little tourmaline.

The hard quartz-tourmaline cores resist the weathering processes with greater success than the remainder of the granite in which they occur, and stand out in relief upon the weathered surfaces as nodules, which are usually between 1 inch and 6 inches in diameter.

The microscopic examination of these granites does not give much additional information. The normal coarse variety is a typical biotite granite, with both orthoclase and plagioclase present.

A perthitic intergrowth of two felspars also occurs. The orthoclase is of later date than the plagioclase in crystallizing out, and even appears to be contemporaneous with some of the quartz. The biotite contains inclusions of zircon, and its crystal boundaries are usually a little corroded.

The fine-grained and pale-coloured variety carries, in addition to the above mentioned constituents, muscovite and tourmaline. The muscovite is not abundant. The tourmaline is strongly dichroic, appearing colourless or deep-blue (sometimes olive-green), according to its orientation. The biotite is very much corroded.

A more detailed discussion of the variations in the character of the granite of Mt. Heemskirk will be found in Mr. Waller's report* on that field.

The area occupied by the granite is much larger than that covered by any other igneous rock of the district. The bulk is also great, for the superior resistance of the rock to denudation causes it to stand out in bold relief.

The granite is clearly part of a plutonic intrusion, which has intruded the pre-existing rocks, whether igneous or sedimentary, without discrimination. Where it has been observed, its boundary with the intruded rocks is always sharply defined.

Disrupted fragments of the invaded rocks are at times visible as inclusions on the granite border, but there is no difficulty in determining the exact limit of the granite where surface-soil and vegetation are absent from the line of contact. No sign whatever of the absorption of the adjacent rock is shown by the granite.

G.—THE PHENOMENA OF CONTACT METAMORPHISM ABOUT THE GRANITE BORDER.

A detailed examination of the contact metamorphic aureole about the granite was not made. However, during a cursory investigation several phenomena of unusual interest were observed. Any deductions that may be suggested by these observations must needs be duly qualified in consequence of the incompleteness of the examination.

A feature which is at once apparent is that the width of the contact metamorphic zone is a very variable one, and that the mineral combinations of this zone are not arranged concentrically about the rim of the granite. Neither have the "contact minerals" (andalusite, cyanite, &c.) been recognised, which are so commonly developed

* G. A. Waller, "Report on the Tin-ore Deposits of Mt. Heemskirk," 1902, pp. 2–6.

where a granitic mass intrudes rocks with a high argillaceous content.

The principal alteration which has taken place is a silicification of the adjacent rocks, as, for example, along the beach north of Trial Harbour, and near the old Tenth Legion Mine, in the Comstock district. The product is a very dense, hard, and tough rock, which is sometimes pale in colour, and at other times so dark that it resembles basalt. With it occur at different points typical lime silicate hornstones. These are best seen at the Tenth Legion Mine, and near Trial Harbour (both on the road and on the beach). At the lastmentioned place the lime silicate rock clearly occurs in the form of lenses in the dense, flinty, silicified slates. Associated with the lime silicate rock, wherever it has been observed, are lenticular masses, in which the prominent constituent is a dark-green clinochlore, sometimes found in very large flakes.

The actual junction of the older rocks with the granite is best seen on the Trial Harbour beach. The line of junction is there well exposed, and its sharp definition at once visible. The granite itself does not appear to throw out arms into the intruded rocks, but a number of small dykes of aplitic material traverse the contact zone, and can be traced back into the granite itself. Blocks of the invaded rocks have been caught up in the granite, and have been retained there as xenoliths all along the line of contact. No alteration of the granite is apparent along its junction with the invaded rocks.

The rocks immediately adjacent to the granite examined in thin sections show a marked development of brown biotite, colourless pyroxene, and sometimes tourmaline needles.

The most remarkable feature in the contact metamorphism is the prevalence of calcic minerals in the absence of any visible beds of limestone or highly calcareous slate or sandstone. Although no analyses have been made of the intruded rocks, it appears certain that the lime content in the contact zone has not all been derived from them.

H.—THE DYKE-ROCKS OF ACIDIC COMPOSITION.

Within the boundaries of the granite of Mt. Heemskirk there occur a large number of dykes which do not penetrate to any considerable distance beyond the igneous border. Small dykes, may be seen, for instance, passing out of the granite into the intruded rocks at several points along the beach about half a mile north of Trial Harbour, but they are insignificant alike in bulk and in length.

The dykes within the granite borders are of the nature of aplites, or rather pegmatites, carrying tourmaline, or even of a quartz-tourmaline admixture. These are more fully treated in Mr. G. A. Waller's report,* and further discussion of them is not necessary. We are concerned rather with those dyke-rocks which have extended for some considerable distance beyond the granite into the surrounding region.

Granite Porphyry.—There are a large number of granite porphyry dykes penetrating the Zeehan field at various points. They are considered to have been derived from the granitic magma, for reasons which are detailed below, and hence are described here.

The description of these quartz porphyries is necessarily based upon altered specimens of the rock, since no underground workings have yet given an exposure of the undecomposed rock.

Those outcrops which are not completely altered by ordinary weathering are situated in immediate proximity to lode-fissures, and have apparently been affected in consequence by the mineralising solutions.

The normal unaltered rock is a pale-coloured granite porphyry, with an excessively fine-grained groundmass. In it occur quartz crystals which are fairly equidimensional, and are sometimes as much as two-fifths of an inch in diameter. The felspar crystals are sometimes very large, as much as an inch and a half along the largest dimension. Phenocrysts of biotite can sometimes be seen in addition.

The more usual appearance of the rock is rather less characteristic of the group in which it is placed. The rock below the weathered crust is dark-green in colour, where it is close to a lode, and the quartz phenocrysts alone are prominent. The outlines of the altered felspars are dimly visible at times, but become apparent on weathering, since the felspars bleach to a paler tint than that acquired by the remainder of the rock. Finally, the rock becomes altered into a soft kaolinised mass, in which the outlines of the felspars are still visible, but from which the quartz crystals can be removed with ease. These latter crystals, with their characteristic crystal forms, may remain

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* *Loc. cit., supra*, pp. 4–8.

almost the only visible indications of the true character of the rock.

With microscopical aid the groundmass is seen to be extremely fine in grain, so that the rock assumes the quartz porphyry facies of the granite porphyry group. Biotite is sometimes present, though muscovite appears to be forming at its expense. The felspars appear to be always sericitised. The quartz crystals remain clear. They are almost always somewhat rounded. The idiomorphic outlines may remain in part, but the corners are usually smooth, and corrosion bays appear. These modifications of the mineral were caused during the period of intrusion; and the corroding agent has been the molten material in which the phenocrysts were being carried upwards, and which afterwards solidified to form the groundmass.

The dark-green varieties of the rock are coloured by chloritic material, which is visible in films and threads throughout the groundmass.

These granite porphyries are clearly dyke-rocks, and no evidence can be adduced to show that they ever reached the surface as the spilite did. They are known only in the form of narrow dykes, the dimensions of which are difficult to ascertain for want of exposures. They intersect the fossiliferous upper strata of the Silurian system, and the rocks older than these.

There are a number of localities, shown on the geological map, in which this rock is found. Most of them are distributed about the western part of the Zeehan field. But at least two occurrences in the township itself have been observed—one in Main-street and the other behind the hospital.

These two occurrences are certainly affected by Post-Silurian faulting. The outcrop exposed at the mouth of the tunnel on Barnett's section is also affected by faulting.

Aplite.—A single case of an aplitic dyke is known within the Zeehan field.

The rock is a leucocratic one of fine grain, and in it are a number of dark-green spots, which appear to mark the presence of former phenocrysts.

The groundmass is white on freshly broken surfaces, and in it felspar crystals can sometimes be detected. The green spots are soft, and are sometimes in the form of fibrous radial aggregates. On joint-planes there is often a deposition of similar greenish material.

Thin sections prove that the rock has a panidiomorphic granular groundmass of quartz and felspar. The felspars are for the most part orthoclase, but a certain proportion of plagioclase is present in addition. The are present a few larger crystals of felspar in this groundmass, both of plagioclase and of orthoclase. In parts of the base a granophyric development is observable.

Large irregular forms filled with slightly pleochroic chlorite are present. These appear to indicate the former presence of some ferromagnesian mineral.

There is only one exposure of this rock, and that is a very small one. It is found alongside a dyke of mica-gabbro which cuts the Comstock Tramway at the Summit cutting. The extent of the rock has not been ascertained, and its mode of occurrence needs further investigation.

I.—BASALT.

An islolated development of olivine basalt has been observed at the point where the Smelters-road crosses the creek draining the Austral Valley.

The rock is a dense-grained one, in which olivine alone may be detected with the unassisted eye.

In thin section these olivine phenocrysts appear partly in their idiomorphic forms, and partly in crystals rounded by magmatic resorption. The crystals harbour numerous minute glass inclusions darkened with iron oxide.

Serpentinisation of the phenocrysts along cracks and from the borders has progressed, in some cases, to the complete alteration of the crystals.

The felspars fill the groundmass with small twinned laths, diminishing in size to terminally-forked and imperfectly-shaped microliths. The extinction angles of the larger crystals, measured from the twin lamellæ, are large and point to labradorite. The felspars, by their parallel arrangement, show a fluidal structure in parts of the rock.

Between the felspars are minute granules of pyroxene belonging to the period of effusion.

The grains of magnetite of the groundmass are diffused throughout it in great abundance, but concentrate irregularly in different parts. In these areas of concentration the grains decrease in size; and, being crowded together, render the groundmass opaque in thin section.

The olivine basalt exposure is a very small one, and has the appearance of being merely the worn-down plug filling the neck or conduit of some isolated volcano. No traces whatever of the ejectamenta or lavas from this pipe now remain.

J.—THE SEQUENCE AND RELATIONSHIPS OF THE IGNEOUS ROCKS.

The rocks of igneous origin which are present in and around Zeehan must not be regarded as isolated and unrelated masses. They are rather the local representatives of the consolidation products from igneous intrusions or eruptions, which have affected considerable areas in Tasmania.

The periods of igneous activity of which the geological structure of the Zeehan field bears witness are those of Cambro-Ordovician, Devonian, and Tertiary times.

The Upper Mesozoic intrusion of diabase, which affected so large a portion of the island, appears likely to have extended over the Zeehan field. The nearest remaining outcrops of the rock are situated to the north-east of Mt. Heemskirk, and on the cap of Mt. Dundas.

I.—The Cambro-Ordovician Group.—Where the older rocks are laid bare at the surface there are distributed over a broad belt of Western Tasmania, which stretches from the northern coast to Macquarie Harbour, and probably still further southwards, a complex series of igneous rocks of this age.

The evidence collected at widely distant localities in this belt serves to show that there exist similar rock-types, and similar variations between the rock-types, at a number of different places.

It has also been ascertained that the conditions under which the Cambro-Ordovician rocks solidified have been very different at different points. Thus typical plutonic rocks have crystallised out of the deeply-seated portions of the molten material at Mt. Darwin and Mt. Farrell. Typically intrusive rocks have been observed to the northward of Mt. Farrell and elsewhere. But the greater part of the exposed igneous rocks of this period appear to have been effusives. They are either lava flows or pyroclastic aggregates, and in many cases the eruptive centres from which they were discharged were submarine.

In general the rock-types which are most abundantly represented in the group are related to the keratophyres or quartz keratophyres. Quartz porphyries, also, are present. But in addition to these acidic varieties there are several more basic types, which are associated with them in the field in such a manner that a common origin must be assigned to both. That is to say, at different phases of the same eruptive period some products issued which were much more basic than those which form the great bulk of the igneous series. The basic varieties are themselves variable in character, and may best be referred to as porphyrites of different affinities.

The crustal deformation which followed immediately after this eruptive epoch has rendered schistose some of the igneous rocks of the group. From the close resemblance of the crushed acidic varieties to certain foreign rocks which have been called "porphyroids," the latter name has been applied also to the Tasmanian types. And since the term "porphyroid" has proved a useful one for field purposes, and a short convenient title for the whole group of rocks of which a large number are strictly so called, it has been adopted in this wider sense by the Geological Survey, and employed in the official publications. But it would now appear that the basic members of the group are more widely distributed and greater in bulk than was at first anticipated, and it is probable that some account will have to be taken of them in group nomenclature.

Referring now to the Zeehan rocks which are to be considered as members of this broad Cambro-Ordovician group, we find pyroclastic representatives of the acidic members in the tuffs and breccias described above.

These tuffs, which are found intercalated with the slates in the Austral Valley, &c., are such as might be produced by the explosive shattering of a keratophyric lava.

The other rocks which are probably to be grouped in this main division are the spilites. For it seems probable that the connection which is beginning to emerge between spilite and some keratophyres will be found to assist in interpreting the relations and taxonomic position of our Zeehan spilite. Some German keratophyres are known to have spilitic structure,* and remarkable keratophyric spilites have been described from Pembrokeshire by Mr. Cowper Reed (containing quartz grains and granophyric quartz felspar aggregates).†

It would appear that the Zeehan spilite can no longer be treated as an isolated occurrence of pre-Devonian lava unrelated to other igneous rocks in Tasmania, but must

* Rosenbusch, "Ergussgesteine," 1908, p. 943.

† Quart. Journ. Geol Soc., 1895, Vol. 51, p. 187: "The Geology of the Country around Fishguard, Pembrokeshire," by F. R. Cowper Reed.

be assigned a place among the varieties of our keratophyres, porphyroids, and porphyrites.

II.—The Devonian Group.—The relationship of the granites and other acidic rocks to the gabbro-amphibolite and serpentine of the western portion of the Zeehan district is also to be considered together with the many similar occurrences in Tasmania. The question has been discussed in some detail in a publication of the Geological Survey.* It is necessary only to state that the evidence supplied by the occurrences in the neighbourhood of Zeehan is wholly in harmony with the view that has previously been expressed—to the effect that the juxtaposition of the acidic and basic groups is caused by magmatic differentiation in some deep-seated igneous reservoir.

While no actual contact of the granite with the basic rocks was observed by us, there were found no signs of the gradual passage of the acidic into the basic types through a series of transitional stages. On the other hand the basic rocks are sensibly uniform over considerable areas, and have certainly undergone some degree of metamorphism.

Hence it appears practically certain that there has been some interval between the periods of the ascent of basic and acidic material, the former constituting the earlier phase of the irruption. That is to say, the differentiation between the acidic and basic material has almost certainly taken place at a lower level, and the differentiated products have ascended separately. Such an occurrence is thus distinct from those where a basic margin to a granitic *massif* has resulted through the operation of differentiation *in sitû*.

The observed dykes of mica-gabbro on the one hand, and on the other of granite porphyry, aplite, and pegmatite, are to be referred respectively to the basic and acidic phases of this irruption.

III.—The Tertiary Basalt.—The sole development of basaltic rock is unrelated to the members of either of the abovementioned groups. It is apparently the denuded neck of some volcano. Assuming that the period of eruption coincided with that of other basaltic outpourings in Tasmania, the basalt attained its present position in Mid-Tertiary time.

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* Bulletin No. 6, "The Tin Field of North Dundas," 1909, pp. 29-32.

The nearest known occurrence of basalt to that of Zeehan is the development at Granville.*

(2)—The Sedimentary Rocks.

The final classification of the sedimentary rocks of Zeehan, and their definite arrangement into the several geological systems, cannot yet be achieved. Nevertheless material advances have recently been made in the correlation of the Palæozoic rocks of Tasmania, and in the knowledge of the stratigraphical position of the correlated groups.

In the light of this increased geological knowledge a revision of the classification of the sedimentary rocks of Zeehan becomes necessary. The former views which were once held with regard to the Silurian age of practically all the sediments in the district have certainly become untenable.

Much work still remains to be done before finality can be attained, and in order that this may be accomplished it will be necessary to make systematic geological surveys of the outlying districts for some considerable distance beyond the limits of the known mineralised area.

The Silurian system is well represented in the eastern portion of the Zeehan field, and, being fossiliferous to a marked degree, has long been correctly classified. But the mistake has arisen of regarding the other older rocks of the district as Silurian also. These are practically devoid of recognisable fossil contents, and their grouping with the true Silurian rocks has evidently been based, in a large measure, upon lithological resemblances; since some of the rocks of finer grain (slates) are lithologically indistinguishable.

The sedimentary rocks which were formerly regarded as Silurian are apparently now to be rearranged in four distinct groupings, only one of which is to be retained within the Silurian system upon unquestionable palæontological evidence.

This rearrangement must be, as has been already indicated, regarded as provisional. Some uncertainties still remain concerning the stratigraphichal position of certain of the formations. The Zeehan district, considered by itself, affords no clues to the solution of these problems in

* See G. A. Waller, "Report on the Tin Ore Deposits of Mt Heemskirk," 1902, p. 1.

stratigraphy. For the district has suffered no small amount of disturbance at different diastrophic epochs, and the boundaries between formations are often coincident with fault-planes. However, with these reservations, the sedimentary succession may be stated to be as follows:—

System.	Representative Formations.
PERMO-CARBONIFEROUS (?)	9. Glacial till.
SILURIAN	8. Pale and dark coloured slates and sandstones. 7. Sandstone, pebbly grit, and greenish grey slate. 6. Limestone. 5. Shale and slate.
UNDETERMINED (ORDOVICIAN ?)	4. Sandstones and slates of the Nubeena and Queen Hills.
CAMBRO-ORDOVICIAN	3. Tuffs, breccias, spilitic lava flows, slates, and sandstones.
CAMBRIAN	2. Tubicolar sandstone. 1. West Coast Range conglomerate series.

A.—THE WEST COAST RANGE CONGLOMERATE SERIES.

The rocks of this series are for the most part conglomerates and indurated sandstones, with a prevailing reddish hue.

These rocks do not enter into the area in which actual mining operations are being carried on, but lie to the southward of it, comprising the high ground of Mt. Zeehan and its spurs and Mt. Professor.

The same formation constitutes a large portion of the West Coast Range, whence it has derived its name.* At the eastern scarp of this range it ends abruptly, being apparently cut off by faulting, but an easterly develop-

* *Vide* Geol. Surv. Tas. Bulletin No. 3, "The Mount Farrell Mining Field," 1908, pp. 23-28.

ment has been found to follow a meridional course along the Denison Range, and southwards across the Gordon River at least as far as Mt. Bowes.*

The rocks of the formation are not wholly free from traces of organic life. These traces are unfortunately not sufficiently well preserved to enable the nature of the organisms to be decided, and the best preserved remains are those of problematical organisms. These are apparently the casts of tubes of tubicolar annelids, which are distributed more abundantly in the overlying rocks, but exist also in the sandstones of this series.

These rocks are succeeded on the east by the overlying tubicolar sandstone, while between the two is a slight unconformity.

The age assigned to this formation is Cambrian, mainly upon the evidence afforded by the easterly development at the Denison Range, which appears to plunge beneath the Ordovician limestone of the Gordon River.

B.—THE TUBICOLAR SANDSTONE.

Overlying the West Coast Range conglomerate series, and separated from it by a slight unconformity, is a white sandstone, containing a number of bands crowded with enormous numbers of tubular casts.

At the point where this formation is best exposed—on the lower eastern slopes of Mt. Zeehan, above the Oceana Mine—the tubes are practically restricted to these narrow beds in the sandstone. The tube-bearing zones are from a few inches to 2 feet in thickness, and are simply horizons in the formation which are crowded with these traces of organisms. The tubes for the most part traverse the beds containing them at right angles or nearly so, but occasionally small tubes may be seen lying in the planes of the bedding.

On a freshly-broken surface the rock is seen to be a massive white sandstone, containing a small amount of pale mica. The organic structures are not at once observed, and are never really well shown. But on the weathering of the rock the tubes stand out in relief, since the material of which they are constituted appears to possess a greater degree of cohesion than the rest of the rock.

In some of the fossiliferous bands there are slightly harder and more resistant layers of sandstone which also

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* See Reports of the Department of Lands and Surveys for 1907-1908 and 1908-1909 and the geological maps printed therewith.

stand out in relief above weathered surfaces. But the tube-casts cross these layers, which do not appear to be of organic origin.

As regards the nature of the organisms which gave rise to the tubes little can be said. No trace whatever of organic structure remains in the casts themselves. They are only compact rods of cemented quartz grains, with a diameter of from one-twentieth to one-fourth of an inch. Those of the Zeehan district are roughly circular in section, and are continuous for a length of as much as 3 inches. In some cases the diameter of the tube becomes larger as it ascends, and a tapering conical cast results, with the largest diameter at the upper end. Other somewhat differently-shaped casts have recently been described from the neighbourhood of the Frenchman's Cap,* but there can be little doubt as to their identity with the more closely crowded casts of the Zeehan field. In all cases the only explanation of the casts which appears to be satisfactory is that they represent the internal casts of the dwelling-tubes or burrows of some tubicolar annelid.

The upper portion of this sandstone formation in Zeehan is devoid of the fossiliferous bands. Near its upper limit there is a narrow band of brecciated conglomerate, which appears to form a fairly persistent horizon.

C.—THE SEDIMENTS ASSOCIATED WITH THE SPILITES, TUFFS, AND BRECCIAS.

There are a number of slightly different varieties of sandstone shale and slate associated with the older volcanic rocks. Of these the sediments associated with the tuffs and breccias present an appearance somewhat different from that of the sediments associated with the spilites.

On the whole, it may be said that the latter exhibit a greater variety of types, which differ *inter se* in colour, composition, compactness, and coarseness of grain. But the slates which occur with the keratophyric tuffs and the breccias are generally softer, of finer grain, and more uniformly coloured (green or greenish-grey, but occasionally chocolate). The latter produce by their weathering an argillaceous soil-stained yellow with limonite, and sometimes also coloured faint-green or purplish.

The slates occurring with the spilitic rocks, on the other hand, are generally different tints of grey, and are very

* Report of the Department of Lands and Surveys for 1908–1909, p. 33.

seldom pale-coloured. They are interbedded with sandstones, which are sometimes quite coarse in grain.

The difference between the two groups of slates may possibly be due to differences in the nature of the materials of which the rocks are composed. From the peculiar colour of the green slates, and the fact that they are constantly found interlaminated with pyroclastic breccias and tuffs, it appears possible that a large portion of the slate itself is really of igneous origin—being due to the gradual settlement of the finer particles under similar conditions to those which existed during the accumulation of the coarser material, which is more obviously a tuff. On the other hand the slates and sandstones which are associated with the spilite are quite normal sediments of aqueous origin.

From the difference between the members of the two groups it appears that there is some slight disparity of age. Yet from the apparent relationship between the igneous material present in the two groups it seems probable that they are to be considered as occupying a single series in the geological column.

The two different stages in the series are distinguished in the geological map, but it is impossible to state which of the two is the older.

The green slates and breccias which are associated with the keratophyric tuffs occupy a tripod-shaped area, with the place of junction of the limbs situated round Manganese Hill. One limb runs towards the Comstock district, one follows the Argent Flat, and the third occupies the floor of the Austral Valley.

The distribution of these rocks is clearly determined by faulting, but the reconstruction of the several members of the stage in the original order of deposition is not yet possible.

The slates and sandstones and the associated spilite lavas and tuffs are situated on the northern and north-western side of the other group, and are best seen in association in the area occupied by the Zeehan-Queen, Oonah, Zeehan-Montana, and Zeehan-Western leases.

All the principal members of the group are also visible in the neighbourhood of Dunkleytown, on a section (67-93M) held by the Zeehan-Western company. The cuttings on the Western Extended tramway, which passes through this section, afford good exposures of them.

The slates and sandstones extend for a considerable distance towards the north-west beyond this area, in which they are found in association with the spilites. They are covered by the Silurian rocks to the eastward, while they appear to run right back to the Heemskirk *massif* on the west.

No signs whatever of organic life have been observed in the sediments of this series.

From their general resemblance to the great series of slates, tuffs, breccias, and lava flows of the western portion of Tasmania these rocks are considered to belong to the Dundas slates, to which a Cambro-Ordovician age is assigned.*

The Dundas slates and breccias are widely distributed in Tasmania, and constitute a series of great but unknown thickness, which outcrops at the surface at a number of points between the northern coast and Macquarie Harbour.

Having been subjected to such earth stresses that rupture and a considerable amount of contortion have been effected, the rocks of the series have not yet been arranged in the order of their succession. At present this is impossible.

D.—THE SANDSTONE AND SLATES OF THE NUBEENA AND QUEEN HILLS.

There are two areas in the Zeehan field in which the sandstones and slates do not appear to belong to the same series as that which is intercalated with keratophyric tuffs or spilitic lavas and tuffs. These are, firstly, the area lying to the south of the slates and breccias of the "tripod"; and, secondly, the ridge of the Queen Hill which lies between the Queen Valley and the Argent Flat. Apparently these two developments are of like age, for they seem to be lithologically similar to one another, and at the same time dissimilar to the other formations of the field. They consist mainly of white sandstones and pale-coloured slates, with occasional layers of dark slate.*

No definite fossil remains have been detected in either of the areas mentioned. But there are, at a number of points, indistinct traces of organisms which do not admit of identification.

What appear to be casts of gastropoda were observed in the north-eastern corner of the Victoria-Zeehan lease

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* See Geol. Surv. Tas. Bulletin No. 5, pp. 8–10, and Bulletin No. 6, pp. 32-35.

* See G. A. Waller, "Report on the Zeehan Silver-lead Mining Field," 1904, pp. 6–7.

(Section 861-93M); rather imperfect moulds of the calyces of some crinoid were found on the Queen Hill; and Mr. G. A. Waller in his geological map of Zeehan has recorded the presence of some brachiopod on the Queen Hill ridge. Many other pits and cavities may be seen in the sandstone which possibly represent the former presence of some organic body, but they are all too indefinite for recognition.

In the absence of any recognisable fossils of stratigraphic value, and on account of the unsatisfactory field evidence of the relationship of these rocks to the fossiliferous Silurian, the age cannot be regarded as ascertained. However, the mine workings on the north-western slope of the Queen Hill ridge show that the spilite dips below the Queen Hill sediments, from which it appears probable that these are the younger series. It may therefore be admissible to place this series provisionally in the Ordovician system.

(3)—The Fossiliferous Silurian Sediments.

E.—SHALE AND SLATE.

The lowest stage in the fossiliferous series is occupied by a loosely-compacted shale, which carries some harder bands of slate.

The total width of the beds is very small. They may be best observed along the Smelters-road and in the railway-cutting just above the limestone quarry.

These shaly beds appear to be the basal members of the true Silurian system, and are succeeded by the fossiliferous stages of the system. In the shales themselves no fossils have yet been observed.

F.—LIMESTONE.

The limestone which succeeds the shale is a dense bluish one, which contains a few argillaceous bands. These latter, on weathering, afford the best-preserved fossils of the whole series.

The only spot at which any considerable bulk of the limestone is exposed at the surface is at the foot of the hill upon which the smelting works stand. At this place the limestone has been quarried to provide the flux required for smelting.

Beyond the limits of the quarry the exposures at the surface are masked by the button-grass vegetation covering the flats which coincide with the areas in which the limestone is developed. No mining operations are at present being carried on in the limestone country in Zeehan, but from the tips of abandoned shafts on the old Despatch lease fragments of fossiferous limestone may be gathered.

Fortunately, however, a collection of the fossils occurring in the Despatch Mine was made by Mr. A. Montgomery, formerly Government Geologist, and was forwarded by him to Mr. R. Etheridge, of the Australian Museum. The fossil species which were then determined are included in the subjoined list. At the present time it is difficult to obtain fossil remains other than corals from the limestone at any other point than the Smelters quarry.

The following fossils have been recognised from the limestone horizon:—

Trilobita:	Asaphus. sp. ind.	Despatch
	Hausmannia meridianus (Eth. and Mit.)	Despatch
	Illaenus johnstoni (Eth.)	Despatch
	Amphion (?) brevispinus (Eth.)	Despatch
Cephalopoda:	Orthoceras, sp. ind.	Despatch
Gastropoda:	Trochonema (Eunema) montgomerii	Despatch & Smelters
	Raphistomina (? gen.), 2 spp. nov.	Smelters
	Hormotoma. sp. indet	Smelters
Pelecypoda:	Leptodomus (?) nuciformis (Eth.)	Despatch
	Palaeoneilo, sp. nov.	Smelters
Brachiopoda:	Rhynchonella borealis, var. nov.	Smelters
Vermes:	Cornulites	Smelters
Coelenterata:	Favosites (?)	Smelters

G.—SANDSTONE, PEBBLY GRIT, AND GREENISH-GREY SLATE.

The next succeeding formation to the limestone is a coarse-grained sandstone, which merges into a grit on the one hand, and into a greenish slate on the other. The coarser-grained varieties are loosely compacted, and ill-suited to preserve the details of organic remains, which are consequently lacking in structural details.

There are present in these beds some obscure tubular casts, which appear to be related to, if not identical with, the similar casts more abundantly represented in the tubicolar sandstone. The principal point of difference between these tubular bodies in the two formations is concerned with their relations to the bedding-planes. In the Silurian beds the tubes lie more or less horizontally, or are inclined at low angles to the planes of sedimentation, while in the tubicolar sandstone they cross the bedding-planes approximately at right angles. In the Silurian beds they are associated with other organic remains, while in the older formation they alone are found.

The sediments belonging to this group are best seen on the ridge of the King Extended Hill and the ridge upon which the smelting works are situated. They dip towards the E.N.E. in the Zeehan field, and appear to plunge beneath the uppermost members of the Silurian system and reappear with the subjacent limestone to the east of the Dundas Rivulet at the old Mariposa Mine; thus apparently outcropping on two sides of a basin.

The number of fossil species represented in these strata is not large, and in this respect there is a marked contrast between these beds and the overlying ones.

H.—SLATES AND SANDSTONES.

The uppermost beds of the Silurian system in Zeehan are light and dark-coloured slates, with which are interbedded white or yellowish sandstones. These are prominently developed in the eastern portion of the Zeehan township, and on the low hills between the township and the Austral Valley, and in the valley of the Little Henty River. They extend in an easterly and north-easterly direction beyond the limits of the area which was investigated by us.

It is highly probable that the basin in which they constitute the uppermost beds does not possess a width of more than about 3 miles, since the Cambro-Ordovician breccias and older slates outcrop as Dundas is approached.

The following list includes the names of the fossils which have been recognised in the beds of this stage and that immediately below it, *i.e.*, in the Silurian beds overlying the limestone:—

Trilobita : Calymene, close to, if not identical with, the typical species C. blumenbachii (Brong.).
Cromus murchisoni (de Kon.).
Hausmannia meridionalis (Eth. and Mit.).

Cephalopoda : Orthoceras, sp. ind. ; Actinoceras, sp. ind.

Pteropoda : Tentaculites, sp. ind.

Gastropoda : Murchisonia.
Raphistoma, sp. ind.
Lophospira, sp. ind.
Lophospira, 2 spp. nov.

Pelecypoda : Tellinomya jonesi (Johnston).

Brachiopoda : Strophomena, sp.
Dalmanella (a form of orthis), sp. nov.
One of the Meristidæ.
Camarotoechia, sp. nov.
Pentamerus tasmaniensis.
Spirifera of the S. sulcata group.
Spirifera of the S. cristata group.
Strophodonta, sp. ind.
Trematospira tasmaniensis, sp. nov.
Rhynchonella borealis, var. nov.
Retzia (?).

Vermes : Cornulites tasmanicus (R. Etheridge).
Annelida (?) ("Pipestems").

Crinoidea : Crinoid ossicles, stems, &c.

Coelenterata : Cast of a Zaphrentoid or Cyathophylloid coral.
Halysites (casts of the corallites).
Favosites (casts of the corallites).
Pleurodictyum.

Writing with regard to the fossils recently collected from the Zeehan district, Mr. W. S. Dun, Government Palaeontologist of New South Wales, makes the following interesting remarks:—"The range of the genera is variable, and on the whole the mean would give a Silurian age, though most probably low in the series, to the Zeehan rocks. The fauna is absolutely unlike any other I have seen from Australia, and some of the species have almost an Ordovician facies. Some ranges are:—

Trematospira	Silurian—Devonian
Rhynchonella borealis	Silurian
Orthis (Dalmanella type)...	Cambrian—Devonian, maximum in Ordovician
Camarotœchia	Silurian—Devonian (?) Carboniferous)
Lophospira	Ordovician—Silurian (? Devonian)
Trochonema	Cambrian—Devonian
Raphistomina	Ordovician (? Silurian)
Hormotoma	? Ordovician—Devonian
Palæoneilo	(Ordovician) Silurian—Devonian

So that you will see the extreme difficulty in arguing from the fauna alone. Still, together with the fossils which have already been identified, I have no doubt of their post-Ordovician age."

I.—GLACIAL TILL.

There are three areas in the Zeehan field in which deposits of glacial till have been recognised.

The material of which the till is composed is a compact, unstratified, bluish-grey clay, in which are studded angular, sub-angular, and rounded fragments, most of which are composed of slate or indurated sandstone.

The largest development extends along the north-western flank of the Oonah Hill, and is marked by the existence of a belt of timber. In the till at this place fragments of granite porphyry were observed, being apparently derived from the Heemskirk district, or from the adjacent areas intruded by acidic dykes.

Another small area, which is ill-exposed at the surface, covered by similar material, is located in the north-western portion of Section 3797-M. A tunnel driven from the creek-level in an E.S.E. direction shows that this till dips under the slate. The line of junction strikes north and south, and dips towards the east at 45 degrees.

Yet another development of the till, also small in extent, occurs on a ridge along which the Western Extended tramway runs, within the boundaries of Section 2872-M. Here the exposure is limited to the cutting along the tramway-line, and gives no information as to the dip of the bed as a whole. Scratched pebbles were found *in sitû* in the till at this place.

The age of these three occurrences of glacial till, if indeed all three are to be grouped together, is a difficult question to decide. On the one hand, the till may represent the remaining fragments of a once-continuous layer forming the bottom of the Permo-Carboniferous system. Lithologically the material is identical with that of which the age is definitely known to be Permo-Corboniferous elsewhere in Tasmania. On the other hand, the till certainly dips under the Cambro-Ordovician slate in the tunnel mentioned above. There may be an inversion of the strata at this particular spot by reason of faulting in post-Permo-Carboniferous time, but no other evidence can be adduced to support this explanation. It seems at least more probable that the till is really Permo-Carboniferous, displaced by faulting, than that it is either Cambrian or Pleistocene. The latter possibility must, of course, be considered, but we know of no post-Pleistocene faulting in Tasmania such that an inversion of the strata might be brought about, while we are aware that a notable amount of fracturing and faulting has taken place all round the island at the close of the Mesozoic era.

A definite opinion upon the age of these glacial deposits must be reserved for the present. It is possible that more definite information will be available when the area lying to the north-west of Zeehan has been geologically examined.

(4)—The Geological History of the Zeehan District.

From what has been said with regard to the difficulty of ascertaining the age of certain of the sedimentary formations and their mutual relationships, it is not possible to state in chronological order the successive events which have led to the present structure and distribution of rock-types. There are, however, one or two matters of certainty upon which some stress should be laid.

It appears certain that there have resulted somewhat complex crustal dislocations, involving the shattering of the rocks, at more than one period. The evidences of at least two diastrophic periods are provided, not only by the observed difference of age between intersecting fracture-systems in the mine workings,* but also by the different degrees of displacement of the Silurian and the Pre-Silurian strata.

The Silurian rocks are considerably disturbed in the Zeehan township and its immediate vicinity, and within this disturbed space the sequence of the several series is not decipherable. But beyond the boundaries of this highly-disturbed area, both to the N.N.W. and S.S.E., the order of superposition of the series is always constant, and the successive formations can be recognised following each other in orderly sequence. There are dislocations in these more regularly disposed beds, but the crumpling characteristic of the vicinity of the township is absent.

But the Pre-Silurian formations are to a much greater degree contorted and fractured. The distribution of the keratophyric tuffs, breccias, and slates is most singular, and can only be explained by supposing that complex faulting has occurred. Moreover, the mine workings have proved that the developments of spilitic lava and tuff are in very many cases truncated by fault-planes or fault-zones.

If the age classification of the Pre-Silurian rocks, which has been indicated above, is correct, there is certainly no displacement of the Silurian rocks comparable with that which has brought the sandstones and slates of the Nubeena Hill in juxtaposition with the West Coast Range conglomerate of Mt. Zeehan. Again, from the information which has been gathered with regard to neighbouring districts similar conclusions have been drawn. The Cambro-Ordovician series includes rocks which are often much

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* *Vide infra*, pp. 81-83.

crushed and folded, while the Silurian rocks are free from notable foliation.

We may therefore conclude that there were two distinct epochs of diastrophism in Palæozoic time, although it is not possible to state exactly the time-interval between them. From the facts that the dykes of granite porphyry are interrupted by the latter faulting, while the lodes themselves are on the whole not materially affected by these dislocations, we believe that the later disturbances of the strata were almost contemporaneous with the granitic irruption.

The sedimentary rocks which are of Post-Silurian age are not of any great importance. The small isolated patches of glacial till, presumably of Permo-Carboniferous age, are the sole surviving remnants in this area of the Upper Palæozoic and Mesozoic sediments which constitute so large a portion of the central plateau of Tasmania.

The presence of the basal beds of the Permo-Carboniferous system in Zeehan (if our surmise with regard to the age of the till is correct), together with the known existence of the Permo-Carboniferous coal measures at Eden,* serve to show that the West Coast region has shared in the marginal fracturing which, at the close of the Mesozoic era, brought about the lowering of the coastal areas around the central plateau.

Since this period of differential movement between the coastal areas and the interior of the island, the progress of denudation has masked the structural features. On the northern and eastern coastal regions the relative downthrow of the marginal strips is still clearly visible in the structure of to-day. But on the western coast the sediments of the upper and lower coal measures and the diabase which forms sills between these beds have been almost totally removed by weathering; and there are exposed at the surface the older Palæozoic rocks, the structure of which was, as we have seen, already complex when Permo-Carboniferous sedimentation began.

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* *Vide* W. H. Twelvetrees' "Report on the Mineral Districts of Zeehan and Neighbourhood," 1900, pp. 105–106.

VI.—ECONOMIC GEOLOGY.

(1)—Mineralogy of the Zeehan Lodes.

A.—GENERAL.

The descriptive mineralogy of the Zeehan lodes yet remains to be worked out in detail. Mr. W. F. Petterd has, in his "Catalogue of Tasmanian Minerals," recorded the occurrence of those species which have been recognised; but much remains to be done in the working out of the chemical composition and crystal habit of the several species. It has not been possible to make a special investigation of these matters during the recent examination upon which this report is written.

The presence or absence of certain minerals in the different ores mined in the district are matters for enquiry when the economic aspect of the lode contents is under consideration. Thus it happens that one lode, the contents of which belong to the siderite-galena type, is of greater economic importance if it contains a proportion of tetrahedrite above the average of the lodes of similar type. The distribution of this mineral—tetrahedrite—is therefore particularly to be noted in the examination of these lodes. On the other hand, those lodes of this same type which contain a higher proportion of zinc-blende than the average are less favourably placed than the lodes free from zinc.

B.—VEIN-TYPES OF THE ZEEHAN FIELD.

It is, of course, already recognised in Zeehan that the distribution of certain minerals of economic importance through the mining field its somewhat variable, and that the variations have an economic significance. But the exact nature of the variations in the mineralogical constitution of the lodes which have caused the variations in their assay value has not received due consideration.

Upon investigation, the mineralogical character of the lode-matter is found to vary from point to point throughout the field. When the lodes which have been worked for silver-lead ore are compared it will be found that the many occurrences may be grouped under a small number of so-called **vein-types.**

The method of thus grouping together similar varieties of lode-matter is a natural one, being based upon the actual mode of occurrence, and the groups which have been recognised at Zeehan must here be investigated in some detail.

The appreciation of these vein-types and of their inter-relationship has a direct economic significance; and the discussion of the different aspects of the question is peculiarly pertinent to the immediate objects of the present enquiry—viz., the investigation of the possibilities of the permanence in the Zeehan lodes at greater depths, and the interpretation of the variations in the lode contents with depth.

The name "vein-type" is applied to a certain definite assemblage of minerals occurring as the filling of veins or lodes. It is applied here only to such paragenetic groupings of minerals as have characteristics which serve to distinguish them clearly from other groups, and which have in many cases received full recognition in different mining fields of the world.

The world-wide distribution of certain types points to the repeated recurrence of similar conditions governing the genesis of the lodes; and the representatives of any given type in Zeehan must be considered together with the foreign parallel occurrences when the genesis is being investigated.

The full description of any particular type is often not an easy matter; especially when, as under the circumstances of our visit to Zeehan, several mines are inoperative, and freshly-broken ore is consequently unavailable for examination. Also, it is not an easy matter to indicate the inter-relationship of various types when development work has not been sufficient to provide the exposures requisite for the formulation of the account of the full sequence of the different types. Again, in the absence of extensive workings, or of a complete record of the phenomena encountered during development, it is impossible to determine all details of the sequence of the vein-filling processes.

Complex occurrences, such as those on the Oonah and Queen properties, where the uncommon types containing stannite are represented, offer certain difficulties in classification which cannot yet be solved.

Any attempt to place these complex assemblages which apparently constitute transitional types into any scheme of classification would be, in the present state of our knowledge, inadvisable. Nevertheless there have been recognised certain clearly defined vein-types which must here be briefly described. The limits between which variations may be found to exist, and the relationship to other types, are briefly indicated where possible, and the remaining matters dealing with distribution and economic importance are further discussed below.

The generalisations involved in the following descriptions must be borne in mind. For the description of a vein-type implies the collection together of the several features presented by a number of different representatives of the type; and the descriptions of types therefore imply a certain responsibility on the part of the authors for the interpretation of the facts of occurrence.

(*a*) *Ores Characterised by the Presence of Oxides.*

(1) *The Pyrite-cassiterite Type.*—The vein of this type within the boundaries of the Zeehan field is a small one, the capping of which has been just uncovered at the surface on the Oonah property, and no further work has yet been done upon it. The small exposure shows almost completely oxidised vein-matter, which is somewhat cavernous in texture. It consists of quartz and cassiterite, with a little pyrite. The tin-ore is grey in colour, and extremely fine-grained and granular. The cavernous texture results, in part at least, from the removal of pyrite, since cubical cavities are frequently quite distinct. The appearance of this weathered ore is in all respects identical with that of the weathered pyrite-cassiterite ore of the tinfield of North Dundas, where the same type is abundantly represented.

A full description of the vein-type has been published by the Geological Survey of Tasmania.*

The existence of this type side by side with the occurrences of tin in the form of stannite is of peculiar interest. The presence of cassiterite in the stannite is noted below.†

While dealing with the occurrence of pyrite-cassiterite ore in the Zeehan field proper it should be noted that a related, although not quite similar, grouping of cassiterite and pyrite occurs to the westward—just outside the southern border of the Heemskirk *massif* at Mayne's Tin Mine. In this case the vein-matter differs from the pyrite-cassiterite ore of Zeehan in that it is associated with abundant tourmaline. Pyrite and cassiterite are also found

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* Bulletin No. 6, "The Tin Field of North Dundas," 1909, pp. 48-52.

† *Vide infra*, p. 53.

together actually in the heart of the Heemskirk granite at the Federation Mine.

Thus the association of pyrite and cassiterite is one which is known to be accompanied by different other minerals in addition to those which have been selected to designate the type.

The term "pyrite-cassiterite ore" used in this report is applicable only to the occurrence at the Oonah Mine; *i.e.*, in the specially restricted sense, except when the contrary is otherwise stated.

(2) *The Magnetite-bearing Types.*—On the western boundary of the Zeehan field, round the edge of the granite of Mt. Heemskirk, there are a number of deposits which are characterised by the presence of varying proportions of magnetite.

It was only possible to make a brief examination of this region, and the description of the types here mentioned cannot therefore be regarded as complete and final. Yet their presence is of far-reaching significance when a comprehensive view is taken of the lodes of the Zeehan field, and they cannot therefore be excluded from a systematic catalogue of the vein-types.

(i) The Magnetite Type.—The most abundantly represented type is that which consists of magnetite without an admixture of other metallic minerals.

The magnetite is apparently often very pure, and occurs in large, irregularly-shaped masses round the edge of the granite. At the surface it appears to be almost entirely free from gangue minerals, but where a prospecting tunnel was driven on the old Tenth Legion Mine (Section 720-M, now charted in the name of the Kynance Prospecting Syndicate, No Liability) a number of very characteristic minerals were found to occur in intimate association with the magnetite; namely tremolite, diopside, garnet, epidote, vesuvianite, calcite, biotite, clinochlore, and serpentine.* Of these minerals the tremolite and serpentine are found to be most intimately associated with the magnetite, while the remainder form the greater part of the zone of altered rock (lime silicate hornstone) in which the magnetite occurs. Of the minerals constituting the lode itself the magnetite is usually massive and without crystalline boundaries, but occasionally cavities are to be seen in which well-formed rhombic dodecahedra have crystal-

* See G. A. Waller, "Report on the Iron and Zinc-lead Ore-deposits of the Comstock District," 1903, pp. 2–5 and Plate I.

lized out. The mineral is strongly magnetic and often polar.

The tremolite occurs in radiating aggregates.

The serpentine is green and massive.

The existence of this variety of lode-matter in the company of the lime-silicate hornstone and of the peculiarly characteristic minerals mentioned above enables us to classify it without hesitation among the "contact deposits," such as have been described from many parts of the world.

Tin ore has been recorded from a magnetite formation belonging to either this type or that described next in order. The occurrence is mentioned by Mr. G. A. Waller in his "Report on the Tin-ore Deposits of Mt. Heemskirk" (1902).

(ii) The Magnetite-Pyrite-Chalcopyrite-Blende-Galena Type.—This type is not a very clearly defined one, and the variations between the different occurrences of ore grouped under this head are considerable.

In assigning an ore-body to this group the character of the gangue minerals present affords criteria at least as important as the presence of magnetite itself.

The ore-bodies here grouped are closely related in actual mode of occurrence to the magnetite bodies which are free from sulphides.

Where most work has been done upon this variety of lode-matter, viz., on the old Silverstream section (No. 5142-93M), now held by Mr. W. Thomas, there is a singular complexity in the composition of the lode-matter within a comparatively small area. Any detailed description cannot be given, but it should be stated that the following associations of metals have been disclosed by the workings on this property:—

(1) Magnetite-pyrite-chalcopyrite-blende-galena.
(2) Pyrite-blende and galena with minor amounts of chalcopyrite.
(3) Chalcopyrite and blende.
(4) Blende and garnet (grossularite).
(5) Pyrite.

Barite has been found in bunches in the lode-matter.

Garnet sometimes forms considerable masses and veins.

Magnetite in one variety largely predominates over the sulphides associated with it, and forms a granular ore of a prevalent black colour, splashed with galena, chalco-

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Loc cit., p. 46. Also "Report on the Iron and Zinc-lead Ore-deposits of the Comstock District," 1903, p. 3.

pyrite, pyrite, and blende. More often the magnetite is not the predominating mineral.

There is an occurrence to the south-west of the last-mentioned where zinc blende and magnetite are associated with the several minerals characteristic of the granite contact zone. This occurrence—on Section 5367-93M—seems to be related to that of the property worked by Mr. W. Thomas. It, too, is characterised by the existence of the non-metallic gangue minerals peculiar to the contact zone.

Without more detailed investigation it is impossible for us to state whether ore-deposition has taken place in the granite contact zone at one period only. It is, however, certain that the formation of mixed magnetite and sulphide ores at one period has resulted, since the minerals are intimately united in a gangue of extraordinary character. The grouping of the minerals is that which is commonly referred to as the "Kristiania type," and which has been recorded from many other parts of the world since its recognition by von Groddeck in the Kristiania region.

(b) *Ores Characterised by the Presence of Sulphides.*

The majority of the types of vein-matter which have been exploited in Zeehan are those in which the metals for which the lodes have been worked exist in combination with sulphur and in the form of sulphides.

In the systematic description of these it will be found convenient to regard the lodes as being on the one hand galena-bearing, and on the other as stannite-bearing. The two groups certainly overlap to a certain degree, but it is thought advisable to keep the varieties carrying appreciable stannite apart from the others, in spite of the presence of minute proportions of tin in some of these. The relationship between the types is discussed elsewhere.*

(1) *The Galena-bearing Types.*—The galena-producing lodes of Zeehan almost all belong to two main sub-groups, one of which is characterised by the presence of pyrites, and the other by that of siderite. Here, again, there is some overlapping of the subdivisional groupings, but yet on the whole there is such a clear distinction that we feel justified in making use of the difference as a basis of subdivision in classifying the types.

(i) Pyritic Types.—These are two in number, and differ chiefly in the amount of zinc blende which is present with

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* *Vide infra*, pp. 68–69.

them. The relationship between the two types of this class is a very intimate one, and the line of demarcation between them is more diffcult to draw in the case of any other two vein-types.

The two types are found together in the field, sometimes in the same lode, and the apparent passage of one into the other is discussed elsewhere.

The Pyrite-Blende-Galena Type.—The mineralogical composition of this type is comparatively simple. The principal constituents are pyrite, blende, and galena, which are named in the usual order of abundance. With these occur a little chalcopyrite, and in some cases small amounts of some antimonial lead ore. The pyrites of at least some of these lodes has been found to carry a small percentage of tin (almost constantly 0·3 per cent. of the pyrite present), which is present as sulphide, and most probably in the form of stannite.

The non-metallic gangue minerals are usually irregularly distributed, and either form irregular bunches or are restricted to narrow bands in the lode. They are almost always siderite and quartz, rarely calcite. However, at the South Comstock Mine the gangue which accompanies the ore of this type is a fibrous radial mineral resembling tremolite.*

The Pyrite-Galena Type.—In this type the principal constituent mineral is pyrite.

Galena and antimonial lead ores occur in the lodes in shoots or bunches.

Small amounts of zinc blende are usually present, and may be found either in bunches or separate bands in the lodes. The distribution of this mineral is not so wide as in the lastmentioned type.

Copper pyrites is also sporadically developed in all portions of the lode-matter, but is never abundant.

There is probably a small admixture of stannite with the pyrite of at least some lodes representative of this type, since analyses of the pyritic portion show between 0·2 and 0·4 per cent. of tin.

Siderite is irregularly distributed, and never assumes important proportions in typical examples of the type.

An insignificant amount of quartz is present in the lode-matter.

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* Cf., "The Geology and Ore-deposits of the Cœur d'Alene District, Idaho," by F. L. Ransome and F. C. Calkins, Professional Paper 62, U.S. Geological Survey, pp. 99 and 175.

(ii) Sideritic Types.—The lodes which are grouped under this heading belong, with one exception, to one type, which has been economically the most important type of the Zeehan field.

The Siderite-Galena Type.—The principal metallic mineral present is argentiferous galena, with which are associated small amounts of some antimonial lead ores.

Tetrahedrite (argentiferous) is found in varying amounts in most of the lodes.

Chalcopyrite is universally present, occurring usually as small blebs included in the galena.

Zinc blende and pyrites are both present in most cases. The proportions of each vary considerably, and in some cases no sign of either can be detected.

Siderite is the common gangue mineral, and it, too, varies considerably in bulk, sometimes constituting almost the whole bulk of the barren portions of the lodes, and at other times where the shoots of galena occur almost entirely disappearing.

Quartz is present in small amount.

The Nickel-Silver Type.—The presence of this type has only recently been discovered in the Zeehan field, and has not been sufficiently exposed for a full description of its contents to be given. It probably belongs to the nickel-silver-cobalt type, which is one of world-wide distribution, but no cobalt has been detected in the samples obtained.

Niccolite is the most abundant metallic mineral, and with it occur galena, some antimonial lead ore, pyrargyrite, and proustite in a gangue of siderite.

The silver contents of this type have proved as high as 530 oz. per ton.

(2) *The Stannite-bearing Types.*—The stannite-bearing types are not easily separated into natural subdivisions, yet there are three modes of occurrence which appear to be, in the light of present development work, quite distinct as far as the main mass of each ore-body is concerned. Two of these occurrences contain the same three minerals, viz., pyrite, stannite, and chalcopyrite, but in very different proportions, and therefore fall naturally into one group, which is divided into a high-grade and a low-grade type.

(i) Pyrite-Stannite-Chalcopyrite Type: High Grade Ore.—The vein-matter here classified is that which is being mined and smelted by the Oonah Company.

The principal metallic minerals present in the ore are pyrite, stannite, and chalcopyrite. With these occur also smaller amounts of bismuthinite, tetrahedrite, wolframite, galena, and antimonial lead ores.

The gangue minerals are quartz and siderite, with occa sional bunches of fluorite.

From the analysis made of picked stannite by Mr. J. H. Levings* it appears that there is a small cassiterite content, and that as much as 15 per cent. of the total tin contents occurs as oxide in some cases.

Mr. Levings' analysis also shows the presence of a little zinc—probably as zinc blende; but the mineral is not visible in the great bulk of the ore. The proportions in which the principal constituents are present may be seen from the following percentage composition of the ore as mined at the present time. The figures have been supplied by Mr. C. H. Stewart, consulting engineer to the company:—

Bulk Analysis of Oonah Ore as Mined.

Silver	22 oz. per ton.
Copper	5·5 per cent.
Tin	4·5 per cent.
Bismuth	0·4—0·45 per cent.
Iron	26—27 per cent.
Sulphur	29 per cent.
Silica	22—27 per cent.
Alumina	4—5 per cent.

Note.—The alumina content is probably derived from the small amount of slate which is enclosed within the lode-matter, and inevitably finds its way into the bins.

The lode contents vary considerably from point to point along the course of the lode. The constituents are frequently arranged in distinct bands parallel to the walls.

The bismuthinite occurs as acicular crystals, usually penetrating the more quartzose portions of the lode, but sometimes also included in the stannite. It may be visible for a few feet along the lode, and then may disappear for some distance.

The wolframite is found in the form of small stout prismatic individuals, seldom exceeding 1 c.m. in length or breadth. It is found in the most siliceous portions of the lode, usually accompanied by chalcopyrite and pyrite, and sometimes by bismuthinite and fluorite.

The galena and antimonial lead ores are usually in narrow veins, but at times form more irregular bunches.

* See Annual Report of Secretary for Mines, Tas., for 1907, p. 32.

Tetrahedrite is especially characteristic of the more quartzose portions of the lode.

Fluorite is not abundant, and is usually to be seen in the form of sporadic crystals enclosed within the quartz.

Siderite is not abundant in the greater portion of the main lode, but is one of the principal constituents of the west carbonate vein, where it is associated especially with chalcopyrite.

It appears that, on the evidence at present available, all these various combinations of minerals must be considered as varieties of what is essentially one type.

The question of the succession of the several minerals distributed in the banded portions of the lode remains unsolved. The same bands are not always in the same place in the main channels, for entirely similar bands will be at one place on the footwall side, and at another place only a few feet distant will be found on the hanging-wall side of the lode.

The final solution of the sequence of the various stages of mineralisation will probably, when attained, satisfactorily explain the seeming complexity of the lode-composition.

Low Grade Ore.—The vein-matter to which this title is applied is that which is worked by Mr. Bruce on tribute from the Oonah Company.

The ore consists almost wholly of pyrite and quartz, with which are a small percentage of chalcopyrite and probably stannite.

The copper pyrites is recognisable with difficulty in the primary ore, but in the upper workings melaconite and bornite were met with.

The presence of stannite is inferred from the fact that assays made of the massive pyrite show an almost constant tin content amounting to 0·3 to 0·4 per cent.

The structure of the lode-matter is massive, and the ore-body mined is a broad one, enclosing a certain amount of unreplaced slate.

(ii) The Pyrite-Stannite-Galena Type.—The vein-matter here described is that of "Clark's lode," on the Zeehan-Queen property. It consists of an admixture of pyrite, stannite, and galena, with little else in addition. A small proportion of quartz is present as a gangue, but is quite inconsiderable. The minerals are arranged either in bands or irregular bunches.

(2) The Variations in the Primary Metallic Contents of the Lodes.

A.—The Nature and Causes of the Differentiation of Vein-Types.

(a) *General Statement.*

It necessarily happens that there are essential and primary differences in character between concentrations of ore which have been produced through the operation of different processes. Thus an ore which has resulted directly from the process known as magmatic differentiation is in general distinct in most respects from an ore of hydatogenetic origin. And ores deposited by ascending hot solutions (hydatogenetic) generally differ widely from ores which are precipitated from surface waters.

In the discussion of the ore-bodies of the Zeehan field we are concerned mainly with hydatogenetic deposits, while on the western limits of the area pneumatolytic and contact metamorphic types are represented. And, since a common origin must be assigned to all the Zeehan ore-deposits which have grown by the addition of mineral material under somewhat different conditions, the several ore-deposits must be considered together as members of a series. The relationship between the ore-deposits formed under different conditions (pneumatolytic, hydatogenetic, &c.), and between those formed under the same conditions, demands investigation.

(b) *Distribution of Metals in the Parent Magma.*

In the consideration of the distribution of the metals near Zeehan, and the causes governing this distribution, we should look firstly at the broadest aspect of the question, and investigate the general features possessed by the Zeehan field which serve to distinguish it from other mining fields in Tasmania.

It is stated elsewhere in this report that the origin of the lodes round Zeehan must needs be an igneous magma which in consolidating has formed the granite *massif* of Heemskirk, and the dykes of quartz-porphyry which penetrate the sedimentary rocks surrounding the granite. For the sake of convenience this magma may be referred to as the "Devonian granitic magma."

This granitic magma has a widespread distribution in Tasmania, and is genetically connected, in our opinion, with the great majority of the ore-deposits of the island. The lithological character of the granite is somewhat variable, but the general assemblage of rock types associated with the granite is peculiarly constant wherever the outcrops have been examined.

The metallic minerals developed in the regions into which the Devonian magma has intruded are not the same in each region, and the differences constitute what are termed "metallographic provinces."

Thus the Zeehan province is one in which silver, lead, and zinc predominate, and in which smaller amounts of tin and copper are also present. It is a province which borders on another (North Dundas) in which tin is strongly predominant, and is but a few miles distant from the copper-rich province of Mt. Lyell. There are occurrences in any one province which serve to show the connection between it and other provinces which may or may not be immediately adjoining.

So we find that the Devonian granitic magma, which at the time of its irruption was probably continuous under a great portion of Tasmania, has brought certain useful metals within accessible distances of the present surface. The irregularities in the distribution of any given metal are in part attributable to the original irregularities in the distribution of this metal in the parent magma. The presence of different metals in different portions of the same magma has on the one hand determined the prevailing character of any particular province, and on the other hand, when a less extended area is taken into consideration has caused variations within the limits of that province.

Thus the first cause of variations in the character of the ores in a mining field is the original variability in the distribution of the metallic contents of the parent magma whence the lodes have sprung.

(c) *Chemical and Physical Conditions Controlling Precipitation.*

It is believed that the metallic contents of the parent magma have been collected together during the progress of consolidation through the agency of the magmatic gases and vapours. As consolidation has proceeded these highly-heated vapours have been expelled.

While within the boundaries of the igneous rock, and probably for some distance into the surrounding rocks, the temperature has been above the critical limit for a number of compounds, chief in importance among which is aqueous vapour. The expulsion of the aqueous vapour and of the mineralising agents has carried the dissolved metallic contents of the magma into the surrounding rock. As these igneous emanations attain an increasingly greater distance from the magmatic hearth they undergo a progressive modification of temperature and pressure.

Inasmuch as decrease of temperature and pressure favours precipitation in the case of the great majority of dissolved metallic salts, it follows that the mineral contents expelled from the magma are precipitated when once the point of saturation of the mineralising solutions is reached. But different metallic compounds are soluble to different extents in any given solution at a given temperature and pressure. So with a solution which is experiencing a diminution of temperature and pressure, a certain point will be reached at which it becomes supersaturated with a certain dissolved substance. At this point precipitation of that substance will commence. And in the case of solutions containing two or more salts of different solubilities, the point of saturation for one salt is different from that for another.

So it may happen that in any channel through which mineral-bearing solutions are passing the precipitation of one metallic compound will begin before that of others. The result of this would be, in the case of ideally uniform conditions, that a succession of zones, each characterised by a different metallic ore, would be developed in the lode-fissure; each successive zone being further removed from the source. The order of precipitation of the ores in any fissure would, under these ideally simple and uniform conditions, be the inverse order of their solubilities.

But in passing from the consideration of ideal conditions to that of the actual circumstances under which ores are deposited, many elements which combine to render uniformity or a regular succession of zones in an ore-body impossible must be taken into account. The channels by which the solutions migrate outwards from the magmatic hearth are essentially irregular in form. Not only do adjacent vein-fissures offer varying resistance to the passage of mineralising solutions, but different portions of the same fissure behave differently in this respect. The rate of passage of the metal-bearing solutions from their place of origin must necessarily be an important controlling factor in determining the point of precipitation of any given mineral. For the more rapidly the solution can move, the further it can migrate before the point of supersaturation is reached. So in the case of two adjacent fissures at points which may be equidistant from the source of the metallic contents of both, there may be differences in the character of the contents which are largely attributable to the differences in the resistance offered by the two fissures to the passage of the mineralising solutions. Again, the thermal conductivity of the rocks bounding the fissures must be allowed for in any complete theory of mineral precipitation; and it is a variable quantity in the different parts of a fissure.

Moreover, it must be borne in mind that this discussion of the chemico-physical principles controlling ore-precipitation deals only with the sequence of events connected with a single stage in the formation of an ore-deposit from a single source.

Although complex factors interfere to disturb the regularity of a zonal arrangement of the metallic ores it is now an established fact that in the case of some ore-deposits there is a definite succession. Thus a passage from galena into zinciferous ores, and thence into low-grade pyrite, has been recorded from more than one American locality.*

This succession of zones of different metallic ores is usually regarded as a vertical succession. However, one of the most significant controlling factors is the distance from the origin, and where the magmatic hearth is not vertically below lodes under consideration but on one side of them, a lode nearer to the igneous source will occupy a similar position to the deeper portion of a lode vertically above its place of origin.

The deposition of the metallic ores about a plutonic igneous mass must take place in the direction in which pressure and temperature are decreasing. So the tendency is for the vapours and solutions to ascend towards the surface existing at the time of the formation of the veins. Long before the solutions reached the surface they had probably dropped their metallic burden—having become too cold to retain the metallic salts in solution. The mineral veins have only become visible after the lapse of long cycles of denudation during which the superincumbent rocks have been gradually removed.

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* W. H. Weed, "Mineral Vein Formation at Boulder Hot Springs, Montana," XXI. Annual Report of U.S. Geological Survey, 1900, Part ii., pp. 249—252.

Thus the actual phase attained in the cycle of erosion is to be taken into account when the vertical succession of minerals in a lode is being considered. The lode may have suffered erosion to a point where the change in mineral contents is just taking place, or the outcrop may be at the top of a zone.

Regional erosion is of positive value where it removes the upper barren zone, but beyond this point it is destructive to the ore-bodies, and tends to remove valuable metal-bearing zones.

The exact limits of the several zones cannot be defined over considerable areas by definite plane or warped surfaces. The complexity of the factors controlling any general zonal arrangement tends to produce very irregular boundaries between different zones, and to make the transition between any two zones a gradual one, in which admixtures of the contents of the two zones are represented.

Thus, it happens that, in a region of marked relief which has been deeply dissected, the theoretical zonal arrangement of the ore-bodies about their source is not at first sight recognisable. Upon detailed investigation certain general characteristics stand out prominently, but exact limits are impossible to define.

(*d*) *Geological Conditions responsible for Variations in the Primary Filling of Lode-channels.*

In the above discussion of the physico-chemical principles involved in the processes of lode-filling very simple conditions have been taken into consideration.

The lodes which occur in any mining field are not as a rule composed of a single mineral or of two minerals where zones of precipitation overlap. They are usually composed of a number of different minerals in association in each zone. The peculiar grouping of minerals resulting from precipitation at approximately the same time is to be named a vein-type.

Where the precipitation of all the constituent minerals of a type is synchronous, the contents of the lode will be determined by the actual materials which can no longer be retained in solution, for reasons briefly indicated above, at that zone. But where there is a succession of different mineral combinations present, as in a banded lode, the materials in solution in the lode-channel during the successive stages of the lode-filling have been different. Thus different materials may attain the same zonal position during an epoch of ore-deposition, and may appear side by side in one lode if deposited during different stages of the epoch. So it may happen that a contributing cause of primary variations in lode-filling is the variable character of the material supplied to the fissure by the source.

It has been pointed out above that the metallic contents of the Devonian granitic magma of Western Tasmania are distributed irregularly.

Since the source of supply is probably not a single point at the lower limits of the lode-fissures it appears possible that different metals, or different proportions of the same metals, may be supplied to different fissures and to different parts of the same fissure. In other words, synchronous vein fissures may draw their supplies of vein-filling material from different portions of the parent magma, and will be filled with different materials where the concentrations of metals within the several portions of this magma differ.

Again, throughout the period during which the deposition of ore has taken place, in such cases as have been in view during the above discussion, there has probably been in progress a continual cooling of the magma. Where ore-deposition extends over a long period the progressive cooling of the igneous rock and its surroundings will cause a gradual approach of the several zones of precipitation towards the hearth. Thus it may happen that an ore characteristic of one of the outer zones of precipitation in the earlier stages of the lode-forming period may, during a later stage, be deposited alongside an ore belonging to one of the inner zones. Such a procedure is possible in all cases in which the same materials have been traversing lode fissures during successive stages of the period of ore-deposition. The same phenomena may result when there are represented in any one locality more than one period of ore-deposition.

Whether two distinct periods of ore-deposition, or different stages of one period, are represented at any locality the result is an overlapping of the zones of precipitation, and the phenomena exhibited by the veins are difficult to explain.

B.—THE VARIATIONS IN THE PRIMARY CONTENTS OF THE LODES OF THE ZEEHAN FIELD.

The application of the general considerations above discussed to the Zeehan mining field is fraught with those difficulties which beset the geologist. The general succession of events may admit of an easy solution where no complex conditions are introduced. But these hypothetical simple and straightforward conditions are seldom met with, and the conditions in Zeehan have proved no exception to the rule. In the first place there is some difficulty in ascertaining the portions of the igneous magma whence the ores were derived. The Devonian granitic magma was without doubt continuous beneath the Zeehan field at some unknown depth, for its apophyses penetrate the rocks of Zeehan itself and the plutonic consolidation products outcrop on the west at Heemskirk and on the east at North Dundas. The upper boundaries of the plutonic rocks which underlie Zeehan are not known, for the deepest mine workings in the central portion of the field give no sign of even the contact metamorphic zone. And it must be borne in mind that, upon the hypothesis which we believe is competent to explain the genesis of the ore-bodies of the Zeehan field, the granite itself is not the source of the vein-matter. A more accurate conception of the ores and the granite is obtained when both the metallic veins and the plutonic igneous rocks are regarded as different consolidation products from one magma. In other words: *the magma whence the ores were derived contained both the metallic contents of the veins, and the non-metallic materials which constitute the igneous rocks.*

Thus, when we refer, as is here done, to the "Devonian granitic magma," we imply a magma from which the Devonian granite is, *inter alia*, derived, and among the consolidation products of which the granite is the most considerable in mass.

The granitic portion of the parent magma is one from which a great part of the metallic contents of the magma have been removed during the processes involved in the earlier stages of solidification. And it thus happens that the granitic portion of the original magma is precisely that portion which is *not* the immediate source of the ores.

Inasmuch as the source whence the metals were expelled is a product of the latest stages in the long process of consolidation it was in all probability deeply seated below an already partly-consolidated mantle of igneous rock, the temperature of which was still high at the period of expulsion. The temperature of the rocks surrounding the cooling igneous mass would be greatest nearest to the igneous boundaries, and decrease with increasing distance from these at the time of ore-deposition. Hence the successive zones of precipitation of the ores would tend to conform also to the igneous boundaries; the decrease in the temperature of the solutions carrying the metals being one of the most potent factors in effecting precipitation.

The pressure conditions cannot be so readily estimated on account of the difficulty of ascertaining the relation of the earth's surface at the period of ore-deposition to that of to-day.

We may be justified on geological evidence in judging the igneous rocks to now possess boundaries not greatly different from those which they possessed at the time of their consolidation beneath the Silurian sediments. A great portion of the overlying sediments having been removed by denudation, the plutonic rocks themselves outcrop on the east and west of Zeehan, which occupies as it were a hollow—notably accentuated by denudation—between two prominent portions of the igneous intrusion. This being so, it appears that the zone of heated rocks lying next to the granite dipped down under the Zeehan field in an easterly direction in the same way as that in which the granite of Mt. Heemskirk appears to do. So too, then, the zones of like precipitation (controlled by the temperatures surrounding the granite) must dip, if our reasoning is correct. In other words, it appears probable that a zone in which one type of lode-matter predominates follows approximately the igneous boundaries, and that above it is an approximately conformable zone of a type differing from the first for the reasons indicated above, these zones dipping in an easterly direction below Zeehan with the Heemskirk *massif*.

The present surface is such that the granite and these successive zones of precipitation are to some extent laid bare. And if the above arguments are valid, it follows that the zone which lies nearest to the granite extends in depth below the zone next in position on passing outwards from the granite.

Thus the succession of ore-zones met with on passing from Zeehan to Mt. Heemskirk is probably essentially the same as that which would be met with if we could penetrate into the crust vertically below Zeehan, or the vertical and horizontal succession of ore-zones are essentially identical in character.

Since we are unaware of the outlines of the igneous rocks beneath the surface we cannot compare the horizontal and vertical distances over which successive zones extend.

The further discussion of the subject must be based upon the horizontal succession, since that alone is accessible to is. Yet we believe that we shall be discussing, in all essential particulars, the vertical variation of primary vein-matter in the Zeehan field. No confusion need arise if it is remembered that irregularities in the geological boundaries or structure, such as have been indicated in the discussion above, will be reflected in the zonal arrangement of the ores. With this warning we proceed to the examination of the zonal succession about the Heemskirk *massif*.

(3)—The Zonal Distribution of the Vein-types in the Zeehan Field.

The area which is taken into consideration in this discussion is, strictly speaking, a wider one than that which may be properly termed the Zeehan field. This, however, is necessary in order that a comprehensive grasp of the relationship of the zones within the more restricted area may be obtained. It has already been indicated that the granite of the Heemskirk *massif* is a derivative of the same magma which we regard as the source of the ores, and moreover that the presence of the great granitic mass has, in our belief, to a great extent governed the precipitation of the ores. We therefore, in the discussion of the distribution of the vein-types, include the southern portion of the Heemskirk *massif* in our field of view.

There are, when we thus examine the whole of this area, certain very definite facts which become evident. The plan of the distribution of the vein-types cannot be shown to exhibit a series of narrow successive zones within which only one type is represented. Yet there are broader zones excellently well defined, which may contain several vein-types within their boundaries. These zones are three in number, and that which is furthest from the granite is necessarily subdivided into two belts. We have named the zones with special reference to the granite of Mt. Heemskirk for the reason that the zone of contact-metamorphism coincides with one of the ore-zones, and has the other two on either side of it.

Thus the three principal zones of distribution may be termed respectively the *Granite Zone*, the *Contact-metamorphic Zone*, and the *Transmetamorphic Zone*. The accompanying map (Plate II.) shows the distribution of these zones.

A.—GRANITE ZONE.

Actually within the borders of the granite of Mt. Heemskirk occur a number of ore-bodies in which the principal mineral of value is cassiterite. Wolframite, native bismuth, and molybdenite are also present, but are less abundant. There is almost invariably present in these ore-bodies the mineral tourmaline. Pyrites is a common associate of the cassiterite when the unoxidised vein-matter is reached.

The cassiterite lodes which have been worked within this zone belong to more than one vein-type, for a more detailed account of which reference should be made to Mr. G. A. Waller's "Report on the Tin-ore Deposits of Mt. Heemskirk."*

The mineral groupings which occur within the boundaries of the granite are found to transgress these limits for short distances. Thus at Mayne's Tin Mine the lodes which are now being worked by Mr. A. Tengdahl and party are intimate admixtures of tourmaline, pyrite, and cassiterite, from the oxidised portions of which pyrite has been removed.

The recent discovery of pyritic ore carrying cassiterite at the Oonah Mine appears to link these cassiterite-bearing lodes of the granite zone with those of the transmetamorphic zone. Yet the representative types of the contact-metamorphic and transmetamorphic zones have not been found within the granite zone.

B.—CONTACT-METAMORPHIC ZONE.

In that area which borders on the granite *massif* much the most significant metallic mineral present in the lodes is magnetite. In this zone the non-metallic minerals are also very characteristic. Diopside, epidote, garnet, vesuvianite, and clinochlore are most widely distributed. On the one hand magnetite ore-bodies practically free from sulphides occur, and on the other hand admixtures of magnetite with metallic sulphides.

Neither the magnetite nor the silicates characteristic of this zone have been found to extend for any distance. Into the granite they do not enter at all, and only one case has been recognised in which the silicate gangue is found beyond the contact zone and within the transmetamorphic zone.

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* *Loc. cit.*, pp. 8–10.

The cassiterite-bearing lode-matter of the granite zone appears to extend into this zone, since at least one instance is known of an admixture of cassiterite with magnetite.

This contact-metamorphic zone is the most well-defined, simple, and narrow of the three principal zones.

C.—TRANSMETAMORPHIC ZONE.

Beyond the limits of the contact-metamorphic zone the ores occurring as oxides are, with the exception of the unusual mineral combinations at the Oonah Mine, no longer found. The primary metallic minerals are found almost invariably in combination with sulphur as sulphides. Yet even within the limits of this zone there is a well-marked difference between two groups of vein-types.

On the one hand we find that the predominant gangue mineral, which forms a considerable proportion of the mineral veins, is pyrite; and on the other it is siderite.

It is at once apparent, when the region as a whole is studied, that the veins characterised by the presence of pyrite may be grouped together in a belt which lies nearer to the contact-metamorphic zone than a corresponding belt which includes the lodes characterised by siderite. Thus we find it necessary to subdivide the transmetamorphic zone into a pyritic belt and a sideritic belt. The exact division between these two belts cannot be drawn as a sharply-defined line, for the passage of one group of veins into the other is marked by transitional types. Neither is the division between the two belts to be drawn as a straight line or a regular curve, for the pyritic belt makes at least one marked incursion into the sideritic belt along the Queen Valley, and embracing the Zeehan-Queen, Oonah, and Montana No. 2 mines.

(a) *The Pyritic Belt.*

The pyritic belt embraces within its limits two main groups, distinguished from each other by their metallic contents, although related in that these occur in combination with sulphur. These have been distinguished above in the catalogue of the vein-types as galena-bearing or stannite-bearing, and it will be convenient to retain this distinction.

(*a*) The galena-bearing vein-types of this belt include the pyrite-blende-galena type and the pyrite-galena type. The former type is especially well represented by the ores of the Comstock district, as, for example, on the South Comstock Mine and Simpson's North Stream, and also on the Swansea and Stonehenge properties. The lodes in the western portion of the Zeehan field, such as Barnett's lode and the lode (Sheargold's) recently worked on the Britannia section, are to be grouped here.

The pyrite-galena type has for representatives Pastkuchen's lode on the Oonah lease, the main lode on the Susannite section, and the pyritic ore-body of the Montana No. 2 Mine.

(*b*) The stannite-bearing vein-types of the pyritic belt comprise the pyrite-stannite-chalcopyrite and the pyrite-stannite-galena types which are developed on the Oonah and Zeehan-Queen properties. These two types occur within the area mentioned above, which is on the one hand connected with the main pyritic belt, and on the other hand extends eastwards beyond the rest of the belt carrying the pyritic lodes, so that it forms a protuberance stretching into the sideritic belt.

(*b*) *The Sideritic Belt.*

The eastern portion of the Zeehan field—that which is most remote from the granite of Mt. Heemskirk—contains the vein-types characterised by a sideritic gangue, viz., the siderite-galena and the nickel-silver types. The former are exemplified by the lodes worked in the Montana No. 1, the Argent, and the Spray Mines. The latter type only appears at one point, as far as is yet known, and though rich in silver contents is comparatively unimportant.

Thus we have ascertained that there is a very definite zonal arrangement of the metallic ores in the Zeehan field. The arrangement which has been indicated in this chapter is not a hypothetical one; it is merely the expression, in condensed form, of the actual mode of occurrence of a number of separate occurrences. Upon us falls the responsibility of correctly interpreting the value of the criteria by which the several occurrences are thus brought together into groups for which a zonal arrangement is claimed. Yet, in assuming this responsibility, we feel confident of the essential accuracy of our grouping, and the more so because precisely similar occurrences have been recorded from other parts of the world, and these have been interpreted in much the same way.

(4)—The Inter-relationship of the Vein-types.

While there can be no doubt about the zonal arrangement of the several types in the manner which has been described, the inter-relationship of the types in the several zones is at first sight not so obvious.

In certain cases it is possible to trace the relationship through transitional types from one zone into another.

The best marked case is that which concerns the relationship of the galena-bearing lode-matter in the contact-metamorphic zone to that of the pyritic and sideritic belts in the transmetamorphic zone.

The magnetite type of the old Tenth Legion Mine in the Comstock district is almost free from sulphides, but nevertheless there are minute specks and films of sphalerite and galena in the lime-silicate-hornstone which occurs with the magnetite. This type is in all essential particulars related to the type consisting of mixed magnetite and sulphides which has been worked by Mr. W. Thomas on the old Silver Stream section.

The occurrence of some fibrous, radiating, greenish mineral, which is probably a pyroxene or an amphibole, as the non-metallic gangue of the adjacent pyrite-blende-galena ore of the South Comstock Mine, at least suggests the close connection between the lode-matter of the pyritic belt and that of the contact-metamorphic zone.

The gradual transition, as the lodes are traced outwards from the granite, does not cease at the pyritic belt, for this in turn merges into the sideritic belt. The passage between the pyritic and sideritic types is well exemplified by the vein-matter of the main Spray lode.*

The succession which has thus been briefly described may be regarded, in our opinion, as beyond doubt due to the effect of differing physical conditions in causing the precipitation of different assemblages of minerals from the same metalliferous solutions according to the distance from the magmatic hearth. In other words, we believe that if a lode typical of the sideritic belt were followed downwards towards its source, it would gradually change its mineral character in such a manner that it would become in turn characteristic of the pyritic belt, and then

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* *Vide* G. A. Waller, "Report on the Zeehan Silver-lead Mining Field," 1904, p. 14.

finally of the contact-metamorphic zone. There are even indications that the contact-metamorphic types may be connected with those of the granitic zone*, but no direct evidence bearing on this matter was obtained during the present brief examination of the contact-metamorphic zone.

With regard to the relationship of the stannite-bearing types to each other and to other vein-types, less information is available, for less development work has been carried out, and some of the workings were at the time of our visit inaccessible. Moreover, the types themselves are more complex than in the case of the galena-bearing lodes. In the state of our present knowledge it would be unwise to attempt to establish the inter-relationship of the types in the form of a vertical succession. It appears to us possible that future work may enable this succession to be established.

The relationship of the stannite-bearing to the galena-bearing lodes needs to be clearly defined, and the necessary evidence appears most likely to be provided by the Oonah and Zeehan-Queen Mines, in which are developed lodes carrying both stannite and galena. There is a visible admixture of stannite with pyrite and galena in the Zeehan-Queen ore, while the presence of stannite in the pyrite of the "galena lode" of the Oonah Mine may be inferred from its almost constant tin content.† But a detailed analytical examination of the ores containing stannite must be carried out before any opinion upon the probable genetic relationship of such ores can be expressed.

It appears probable that the stannite-bearing lodes have been deposited from solutions which have brought upwards an assemblage of metals distinct in many respects from that which migrated in the solutions which deposited the galena-bearing series of vein-types which have been discussed above.‡

But while the metallic contents of the solutions which have deposited the two apparently distinct series of lode-types have been different there has been probably some degree of similarity between the compositions of the different solutions. The existence of several minerals in both the stannite-bearing and the galena-bearing lodes indicates that the solutions which have deposited these minerals have possessed a similar dissolving power, and

* *Vide supra*, p. 64. † *Vide supra*, p. 51. ‡ *Vide supra*, p. 50.

that they have in consequence been capable of bringing similar materials from the sources towards the surface.

In the absence of many minute analyses it is impossible to state in quantitative terms the essential and determining points of difference between the stannite-bearing and the galena-bearing series. For no careful search has yet been made for the presence of tin, bismuth, tungsten, or fluorine in the galena-bearing lode-matter. Bismuth, tungsten, and fluorine are certainly present in combination in visible proportions in certain of the stannite-bearing lodes, but not in all. Again, in the case of both stannite-bearing and galena-bearing lodes there is a common feature in the development of graphite in the wall-rock immediately adjacent to the lodes, where these traverse slate country.*

(5)—The Variations within One Vein-type.

From the above mention of the apparent passage of one vein-type into another, with the development in certain cases of transitional types, it is evident that a certain amount of variation must take place in the contents of the lodes considered to belong to one type. For the mineralogical definition of a vein-type must needs be to some extent a generalisation, which embraces the results of observations at a number of points upon one lode or upon a series of essentially similar lodes.† In certain cases at Zeehan, especially in the high-grade stannite-bearing ore of the Oonah Mine, the variable nature of the ore which has here been grouped within one vein-type is most marked.

The variability of a type is expressed on the one hand by the tendency towards the development of mineralogically different bands in the lode, and on the other hand by the gradual change in composition in the lode-matter through the appearance or disappearance of certain minerals. In the former case the composition of the mineral-bearing solutions has altered from time to time during the filling of one portion of the whole lode. In the latter case it sometimes appears that there has been only one period of lode-filling, but that the constituents present in solution have been different in different lodes,

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* *Vide infra*, p. 94.
† *Vide* R. Beck, "The Nature of Ore-deposits" (Weed's translation), Vol. I., p. 192.

or in different parts of the same lode, during a single epoch of precipitation.

The most marked way in which the variability of the lode-matter is displayed is that which has been revealed by the development of the ore-bodies; namely, the distribution of pay-shoots in the lodes. These shoots are in many cases determined by the structural features of the lode-fissures, which bulge and contract along the course of the lodes in such a manner that only the bare track of the fracture can be detected between the lenses of ore.

But even in one lode the character of the filling of adjacent lenses is not constant, and within a single shoot or lens of ore the proportion of gangue minerals to the valuable ingredients is different at different points. These features are exhibited by many lodes, as an example of which the "No. 2 lode" of the Zeehan-Montana No. 1 Mine is an example.

Another respect in which the lode-matter shows a tendency to vary is observed when the silver tenor of the sideritic galena lodes is examined. Taking again the Montana No. 1 Mine as one from which to illustrate this statement, we find that the No. 1 Lode (now exhausted) carried an average silver value which was much higher than that of No. 2, No. 3, or No. 4 lodes. The first-class ore from No. 1 lode is stated to have averaged 124 oz. of silver per ton, while that of No. 2, No. 3, and No. 4 lodes averages 100 oz., 80 oz., and 90 oz. respectively. Nor is this the only irregularity which has been remarked with regard to the silver contents, for in any one of the lodes mentioned the first-class ore has not a constant tenor.

It is stated that there is no appreciable decrease in the proportion of silver in the ore as the lodes have been worked at greater depths. But wherever a large pocket of ore occurs—notably at the intersection of the ruscheln with the lode-fissures—it is found that the silver content of the ore is higher. This is apparently caused by the presence of argentiferous fahl-ore in larger proportions than usual at such points in the lodes; but no reason can yet be afforded for this singular distribution of the mineral. It is one of the facts of occurrence which must be constantly borne in mind with a view to the ultimate discovery of its rationale, and the application of such possible discovery to future prospecting.

Another mineral which is present in the sideritic galena lodes in very variable proportions at different places is sphalerite. This mineral is abundant along the Silver

King-Zeehan Bell line of lode, but it is almost entirely absent from the Montana Mine; yet the lodes of these two portions of the field are essentially similar in other respects as far as mineral composition is concerned. In such cases it appears clear that there has been a difference in the materials supplied to the different fissures,* but that the difference is not sufficiently great to justify a classification into distinct types or sub-types. This phenomenon is quite distinct from that which is found when we pass in review from one vein-type to another, *e.g.*, from the sideritic-galena type to the pyrite-blende-galena type.

(6)—Economic Consideration of the Vein-types of Zeehan.

A.—The Relative Importance of the Several Types.

It has been explained that the vein-type is an assemblage of minerals which are found in association, and that the whole assemblage is the geologically important matter for consideration. Different vein-types may contain the same mineral, such, for instance, as galena or tetrahedrite. And in a single vein-type different minerals are found, sometimes segregated apart so that they form shoots or bands in the lodes. Hence it is that from different vein-types the same metals have been won, and also that from the same vein-type different metallic ores have been mined.

Argentiferous galena has been obtained in greatest bulk from the siderite-galena type, but has also been won from the pyrite-blende-galena, the pyrite-stannite-galena, and the pyrite-galena types.

Stannite has been won from the pyrite-stannite-chalcopyrite (high grade) and the pyrite-stannite-galena veins.

Pyrites for the manufacture of sulphuric acid has for some time past been regularly exported from Mr. Bruce's tribute on the low-grade pyrite-stannite-chalcopyrite ore of the Oonah Mine.

In addition to these primary ores there have been worked from time to time a few oxidised ores or gossans for sale as fluxes. In some cases these are plainly ores which have resulted from the oxidation of one or other of the types mentioned above. In other cases they have not been exposed to such a degree that the primary contents of the vein-types whence they have been derived can be determined.

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* *Vide supra*, p. 60.

Of the ores that have thus far received scarcely any attention the most important are the ores of iron and zinc.

Zinc-blende may be won from the magnetite-pyrite-chalcopyrite-blende-galena type which occurs in the Comstock district at several points in the zone of contact metamorphism. It is also to be obtained from the pyrite-blende-galena, and even from parts of the siderite-galena types.

The magnetite ore-bodes are large, and appear at the surface to be exceptionally free from admixture with deleterious ingredients.

The recently-discovered occurrences of the pyritic-cassiterite and nickel-silver ores at Zeehan have not yet been opened up, and consequently no estimate can be formed of their economic importance.

In reviewing the list of productive lodes on the Zeehan field, we find that those which have hitherto contributed most largely towards the output of silver-lead ore belong to the siderite-galena type, and that the pyritic types carrying galena have only afforded small amounts in comparison.

The stannite ores have been worked in the past mainly for their silver and copper contents, but the recent successful smelting of the pyrite-stannite-chalcopyrite ore by the Oonah Company has rendered this type of vein-matter of immeasurably greater importance than hitherto.

B.—THE RANGE OF THE COMMERCIALLY IMPORTANT MINERALS THROUGH THE SEVERAL ZONES OF VEIN-TYPES.

It has been indicated above* that there appears to us to be at least one clear succession of genetically related vein-types which can be traced through a series of zones† surrounding the granite of Mt. Heemskirk. From the foregoing discussion of the relative importance of the several types as sources of the different metals it follows that certain metals have a long range, although they are not equally developed throughout this range. Thus, for example, galena is found in all the types, but is much the most abundant in the sideritic belt of the trans-metamorphic zone. The distribution of the several minerals is shown best by the accompanying diagram (Plate III.), which is essentially that drawn by Mr. G. A. Waller for his report on the Zeehan field in 1904.‡ It has been amended

* *Vide supra*, p. 67. † *Vide supra*, pp. 63-67. ‡ *Loc. cit*, Plate 2.

and expanded in order that the more recent developments may be accorded due recognition, and that the names given in the several zones may correspond to those given above in this report.

Inasmuch as a detailed examination was not made of the granite zone the range of all the lode-forming minerals found in the district and its surroundings cannot be included in the diagram, but the principal lode constituents are shown.

This diagram affords a ready graphic means of investigating not only the range of each separate mineral, but also the range of mineral groupings, and the difference between the points of maximum development of different minerals.

The significance of the gangue minerals is at least as great as that of the valuable constituents of a vein-type when the question of the zonal position of a lode requires to be determined.

The present position of silver-lead mining in Zeehan demands that special reference to one matter be made in this place, since the diagram materially assists to explain the interpretation which appears to us sound.

With the depletion of the galena shoots in certain of the siderite-galena lodes it has been found that the lode-filling is almost solely composed of siderite, and the fear has been expressed that the lodes have become permanently barren, galena being replaced by siderite. Now, if this were really the case we should find a galena zone giving place to a zone in which siderite predominates. Far from such being the state of the distribution of galena and siderite, we find, as a matter of fact, that siderite decreases in bulk as the lodes are traced towards the granite zone, and that it decreases even more rapidly than does galena. It has been stated above* that we believe the decrease which can thus be traced as the granite is approached is exactly equivalent to the decrease which would be found if we could follow any one lode downwards through successive zones of precipitation towards its source.

The essential point that must ever be borne in mind is this: that the galena and siderite must be regarded as constituents of one vein-type rather than as separate types consisting of one mineral only.

It has also been already pointed out† that the siderite-galena vein-type merges gradually into pyritic types.

* *Vide supra*, p. 63. † *Vide supra*, p. 67.

This transition is marked by the decrease in the proportion of siderite and a corresponding increase of pyrite.

Yet, while these gangue minerals –siderite and pyrite—alter, and serve to indicate the zonal position of the type according to the proportions in which they are present in the lodes, the galena does not disappear at the point where siderite gives place to pyrite. Its existence is shown in the diagram to be known right down into the granite zone. Certainly it is most abundant in the sideritic belt, and it decreases in quantity from that belt downwards; but it is important to note that it does still continue in the lodes of the lower zones.

If, then, we return to the investigation of those particular cases in which lodes have apparently lost their galena contents and "turned into siderite" the explanation to be offered is this: The mines in which these phenomena have been noticed are situated within the sideritic belt of the transmetamorphic zone. The galena in the lodes is distributed in shoots such that there is both a vertical and a horizontal variation in the character of the lode-matter. Thus it may be found that on any one level galena may predominate at one point and siderite at another; or that siderite may take the place of galena at another level either higher or lower than that in which the galena occurs. It cannot be granted that at a shallow depth below the surface galena is entirely replaced by siderite. The very presence of the siderite is clear proof that the pyritic belt has not been reached in the work of development, and this in itself should afford some satisfaction to the mining companies confronted with the problem. It is true that galena continues beyond this sideritic belt, but it is certainly most abundant within the belt. In the case of certain of the mines there is no sign whatever of approach to the pyritic belt in the deepest workings. The geological evidence which we have gathered during our investigation is wholly opposed to the belief in a barren zone at a shallow depth beneath the surface.

(7)—The Secondary Alteration of the Zeehan Lodes.

The primary ores of Zeehan, as of every other lead field, have suffered to some extent from the action of weathering. Weathering agencies cannot have begun to oxidise the primary lode-matter until the progress of denudation was so far advanced that the rocks above the zones of mineralisation were removed, and the ore-bodies themselves came within reach of the circulating surface waters. For there can be no doubt but that all the primary ore-bodies of the field were formed at a very considerable distance below the surface, a distance at least sufficient for the crystallisation of the typical plutonic rock—granite—of Mt. Heemskirk to take place. The minerals of the lodes are certainly typical of the contact metamorphic deposits or deeper vein-zones.*

The removal of the rockmasses which lay immediately over the present surface has undoubtedly been accompanied by the removal of some portion of the lodes themselves, but it does not appear possible to determine the amount of lode-matter which has thus been lost. If we had some means of estimating the original vertical range of the ore-bodies, and could ascertain the relationship between this range and the present surface, the zonal horizon of the several outcrops could be ascertained. This, however, is not a matter of moment, since we believe† that the evidence afforded by the horizontal succession is equal in value to that which might be obtained from the examination of a long exposure of the vertical succession.

Apart from the mechanical disintegration of the lodes, their chemical alteration requires investigation. Whereas the mechanical effects of denudation are wrought solely upon the actual outcrops of the lodes, the chemical alteration proceeds below the surface and may even materially assist later disintegration. The chemical alteration of a lode is effected by the percolation of meteoric water through the upper portion of the earth's crust. The composition of the minerals which result from the alteration depends principally upon the nature of the unaltered lode-matter, but also partly upon the composition of the country-rock in the immediate vicinity of the lode.

The valuable minerals which have thus been formed in the Zeehan field have in no case been important in bulk.‡ The gossanous masses which result from the weathering of the lodes are due mainly to the oxidation of siderite and pyrite. The manganese content of the siderite gives rise to the pyrolusite or psilomelane of the gossan. With these gossans there sometimes occur small quantities of valuable minerals, and when native silver or silver

* *Vide* W. Lindgren, "Economic Geology," Vol. II., No. 2, 1907, p. 123.

† *Vide supra*, p. 63.

‡ *Vide* G. A. Waller, "Report on the Zeehan Silver-lead Mining Field," 1904, pp. 26-32.

chloride are present the gossans may become of commercial importance. Lead is present as cerussite, anglesite, or pyromorphite, but there have never been worked any considerable bodies of oxidised lead ore in any part of Zeehan. The argentiferous gossans have been mined, and have incidentally carried a lead content, but these gossans have been sought primarily as fluxes, not as ores of lead.

These gossanous outcrops are in the majority of cases on the higher ground at Zeehan.* They are by no means universal, and have not proved to be unfailing indications of the presence of large bodies of ore below. In this connection it must be borne in mind that any large barren portion of a lode, if composed of siderite, will produce a considerable gossan.

The rate of denudation in the Zeehan field has been sufficiently rapid to cause the continuous removal from the majority of the lodes of any oxidised crust that might form.

Since the formation of a deep zone of weathering is almost entirely dependent upon the topography and the rate of erosion, it appears improbable that there has ever been any considerable oxidised zone above the primary ore. If there has been, in the past, any such development of oxidised ore when different topographical features obtained, the present stages of the cycle of erosion have completely obliterated all traces of it.

In those cases in which the weathering of a galena-bearing lode has proceeded at a rate much greater than that of erosion the production of an oxidised zone is not the only alteration that takes place. The metallic contents of the upper portions of such lodes may be almost completely removed in solution, so that an impoverished zone is left at the surface.

But while the outcrop may thus suffer a loss of its metallic contents the surface waters, where favourable conditions exist, transfer this material to a lower portion of the lode, and there deposit it. The precipitation of ore from descending meteoric waters by chemical interaction with other metallic compounds, whether these are in solution or exist in the solid form as original constituents of the lode, is called secondary sulphide enrichment, for the minerals thus formed are for the most part sulphides.

* In almost every case these gossans are situated above the level of the dissected peneplain of the Little Henty River mentioned above in the chapter on the physiography of the district. *Vide supra*, pp. 9–14.

These secondary sulphides, where they occur, occupy a more or less clearly defined zone between the weathered and the primary ore. There are usually marked differences in character between the secondary and the primary sulphides of an ore-body which has undergone such alteration.

Where the primary ore is complex in character the different secondary sulphides are often deposited in separate zones above the primary ore, and only such minerals can be formed as may result from the molecular readjustment of the constituents of the primary ores.

While sulphidic ores are characteristic of this zone of enrichment there are present with them oxidised compounds in subordinate amount.

There is commonly some crystallographic difference between the habit assumed by any given mineral, according to whether it is primary or secondary.

The silver contents of secondarily enriched lead ores are commonly higher than those of the primary lode-matter, or there are found with the secondary lead ores very rich patches or pockets of silver ore.

The opinion has been expressed that the valuable shoots of sulphide ore which have been worked at shallow levels in the Zeehan field are secondary enrichments, and that these shoots of secondary origin give place to unpayable primary ore at no great distance below the surface. In fact, it appears to be a commonly-held opinion that the normal unaltered ore of the Zeehan field is composed of siderite with traces of galena, while the secondary ore consists of a galena-siderite admixture in which galena is present in payable quantities. This opinion we believe to be wrong, and to be based upon an entirely false conception of the relationship of the galena to the siderite. We desire to insist upon the recognition of certain definite facts of occurrence which have a direct bearing upon this question:

(1) There is no difference whatever between the character of the lode-matter at the very surface of many mines and that at the deepest levels. The Montana No. 1 Mine affords excellent examples. The ore occurs in shoots, but the character of the ore in the shoots is identical at all levels. It is built up of precisely the same minerals at all horizons, and in no way could an estimate be formed of the zonal position of any specimen of ore from the same lode.

(2) The absence of oxidised ores with the sulphides in the normal ore of the field at any level is in itself good evidence of the primary character of all of the ore. Since the surface ore is entirely similar to that obtained from a depth of several hundred feet, the mode of deposition of both must needs be identical. The silver-lead ores of Zeehan belong to definite primary vein-types of world-wide occurrence. There can be no doubt but that all such occurrences have a similar origin.

(3) There is a general absence of leached and weathered ore at the present surface which may be regarded as a zone from which the ore at lower levels can have been derived. It need hardly be pointed out that the formation of a zone of secondary sulphide enrichment cannot result without the presence above it of a complementary impoverished zone. There is no evidence of the former existence of any leached zone above the majority of the lodes. The physiographical features of the region appear to preclude the probability of the existence of any such zone in the past at so small a distance above the present outcrop that the present undenuded lode-matter can have received from it an addition of material through the agency of descending surface waters.

(4) It is necessary, for the precipitation of lead in the form of galena from solutions in which lead sulphate or lead carbonate is present, that other sulphides should be present in the primary ore. Pyrite or sphalerite may thus cause the deposition of galena.* Now, in the case of certain of the Zeehan lodes, in which the shoots of galena have been considered to be of secondary origin, there are present no such other sulphides as could have caused precipitation. Pyrite is almost entirely absent, and sphalerite is present in such small amount that its effect must be inappreciable.

So, although a zone of secondary sulphides may be developed above the primary ore in the case of galena-bearing lodes of pyritic type, it seems improbable that, in the case of most of the Zeehan lodes of sideritic type, a

* R. Beck, "The Nature of Ore-deposits" (Weed's translation), Vol. II., p. 380. Also, W. H. Weed, "The Enrichment of Gold and Silver Veins" in Genesis of Ore-deposits, A.I.M.E., 1901, p. 488.

secondary enrichment of this kind could attain such proportions that it would be of economic importance.

In view of these insuperable objections to the view that the galena shoots of the principal mines of the Zeehan field are due to superficial reconcentration, it must be conceded that they are caused by primary variations in the distribution of the lode contents.

(8)—The Structural Features of the Lodes.

While it must be granted that the Zeehan ores have had their origin in the magma of which the Heemskirk granite *massif* forms the most prominent consolidation product, the exact loci of the ore-bodies are determined by certain structural features of the rocks beyond the limits of the parent magma.

On emerging from the igneous hearth the metalliferous solutions have been forced upwards, and in their ascent have been restricted to certain definite channels in the country surrounding the granite. These channels are fractures in the earth's crust, some at least of which have originated at a period nearly coincident with the Devonian invasion. By these the Silurian rocks have been fractured and disturbed, as also the apophyses from the granitic magma itself.*

Preference as loci of ore-deposition has been given to certain fractures rather than to others. Those which obtained the preference either afforded a more ready passage to the metalliferous solutions, or they attained, at their lower limits, more closely to the actual points of supply. In some cases the ore-channels are simple fractures, and in other cases the metalliferous solutions have ascended along the intersections of certain fracture-planes with others or with crushed fault-zones.

Those structural features which are of greatest economic significance are here discussed.

A.—Features connected with the Ruscheln.

The most important matters to be explained with regard to the lodes in the portion of the field which is being most actively worked, viz., in the area including the Oonah and

* The period of earth-fracturing did not entirely cease with the deposition of the ores, for a few cases of actual dislocations of the lodes are known. But these instances are uncommon, and the dislocations of the lodes are not large.

the Zeehan-Montana Mines, are the relations between the lode-fissures and the principal cross-courses or "slides," and the consequent control of the distribution of ore.

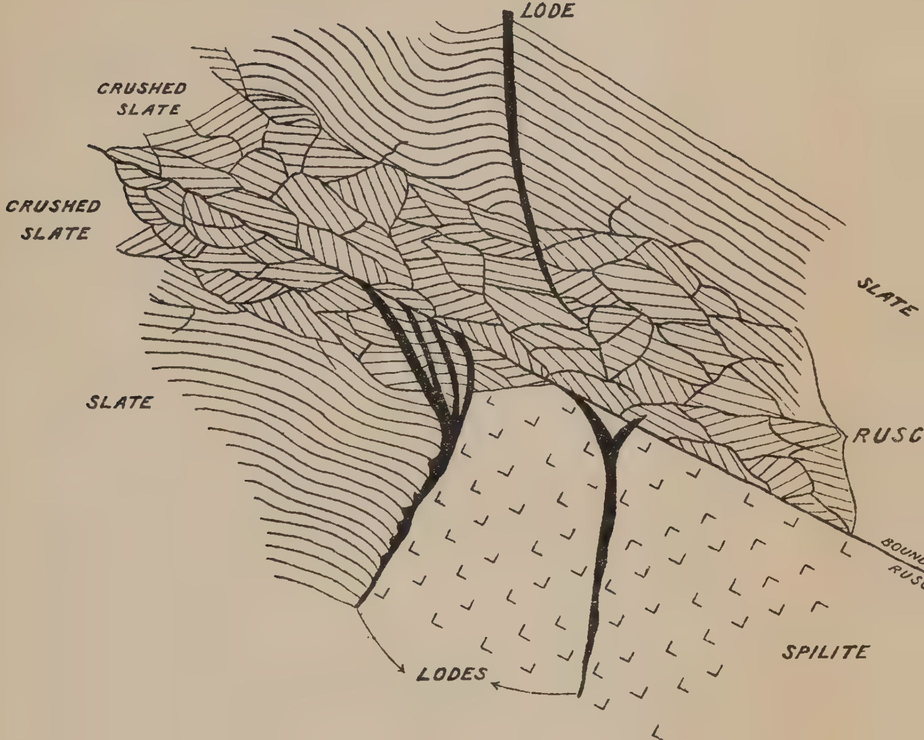
The several points which call for investigation are here discussed separately.

(*a*) *The Nature of the Cross-courses.*

The cross-courses or slides which appear to cut off some of the ore-bodies are not always, in the cases which we were able to inspect, planes of dislocation of a simple character. In some cases it was observed that the slides were fault-planes, showing a width of $1\frac{1}{2}$ to 2 feet of crushed rock; *e.g.*, the slide on the Oonah property and the "No. 2 slide" in the Montana Mine. But in the case of the main (No. 1) slide on the Zeehan-Montana No. 1 Mine, with regard to which the development work has provided the greatest amount of available information, it is clear that the displacement of the country has resulted in the production of a broad zone of broken rock. It is now known that this slide extends at No. 3 level for a width of over 150 feet; that the fault-zone as a whole dips to the north-east at an angle of about 45°; and that while there is commonly a well-defined footwall to this broken zone, there is no equally well-marked hanging-wall. The sharp definition of the footwall is aided by the fortuitous occurrence in some parts of the Montana Mine, to the eastward of No. 3 lode, of spilite on one side and crushed slate on the other side of the footwall boundary. Where slate occurs on both sides the exact boundary of the broken zone is hardly recognisable. This is the case with regard to the hanging-wall side of the "slide," and therefore an accurate estimate of the width of the affected zone is not readily to be obtained.

Within the boundaries of this fault-zone there are very numerous subsidiary fractures, and the slate between is much crushed and crumpled. Slickensides caused during this crushing are very numerous. The subsidiary fractures and slickensided surfaces exhibit only a general tendency to follow the dip and strike of the fault-zone as a whole.

These fault-zones are precisely similar in character to the *ruscheln* of the German miners. One of them, the No. 1 or main slide of the Montana Mine, has been observed over a length of 1100 feet in the Montana Mine alone. If the same slide is continuous through the Western Mine, along the course of what has been called by


LODE
CRUSHED SLATE
CRUSHED SLATE
SLATE
SLATE
RUSC
SPILITE
LODES
Fig I

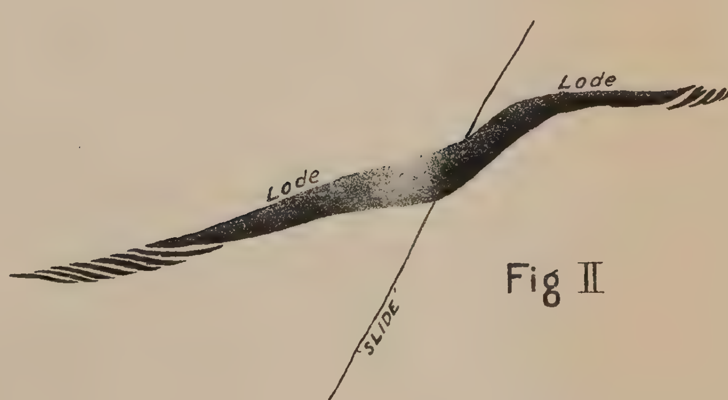

Lode
Lode
SLIDE
Fig II

PLATE IV

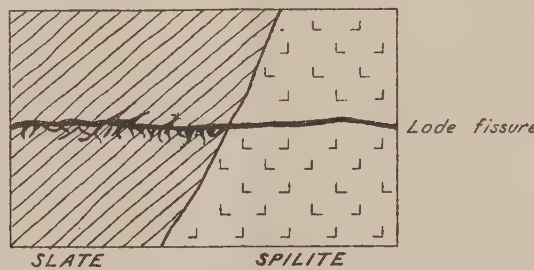


Fig III

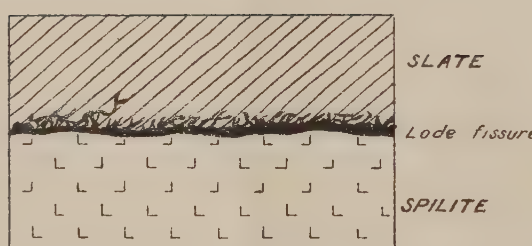


Fig IV

IAGRAMS TO ILLUSTRATE
LODE STRUCTURE

W.D.R.

L. Keith Ward
Assistant Government Geologist
May 3rd 1910.

Photo Algraphed by John Vail Government Printer Hobart Tasmania

Mr. G. A. Waller* the No. 4 lode, the horizontal extent proved is 2500 feet. In the case of the other slides which have been recognised on the field there has not been sufficient ground opened up to determine their length.

The *ruscheln* have been found to continue down without interruption to the lowest depths reached, and have been evidently produced by the rupturing of the crust under powerful stresses. There has been a displacement of the country traversed by the main *ruschel* of the Montana Mine, but the amount of the displacement is not measurable, nor is it known in what direction the movement between the walls has taken place. Yet from the results produced in the accessible portion of the affected zone it would appear certain that the influence of the faulting must extend downwards for a great distance—beyond the limit of profitable working.

It is noticeable that the No. 1 and No. 2 slides of the Montana Mine junction near the north-western limit of the main shaft workings. An actual junction was, we are informed, never observed, but the country at this place was very much disturbed. With the occurrence of a series of these diverging fault-planes may be compared the structural features of the St. Andreasberg district in the Harz Mountains.†

(*b*) *The Relative Age of the Lode-fissures and the Ruscheln.*

This question is not altogether a simple one to decide. Although the two sets of fissures come in contact with each other, the phenomena observable at the intersection of the two may at first sight give the impression that the cross-courses have been formed at a later date than the lode-fissures. Yet we firmly believe that the lode-fissures are of later date than the *ruscheln*, for the following reasons:—‡

(*a*) Certain of the lode-fissures certainly do penetrate the broken zone, and have a regular unbroken con-

* Mr. G. A. Waller, in his "Report on the Zeehan Silver-lead Mining Field," 1904, p. 38, states his belief in the identity of the slide with the lode mentioned. On account of the flooding of the Western Mine we were unable to investigate this important matter.

† See H. H. Thomas and D. A. MacAlister, "The Geology of Ore-deposits," 1909, pp. 188–189, and especially Fig. 43.

‡ The principal features of the *ruscheln* are shown in the accompanying diagram—Plate IV., Fig. i.

tinuity within the belt of rock of which the chief characteristic is the irregularity of the fissuring. The north-eastern (hanging-wall) boundary of the main *ruschel* of the Montana Mine has been assumed to have been reached when one of these later fissures has been met with, probably because it was once thought that no continuous lode-fissure could exist in the broken zone. However, recent developmental work has definitely proved that the *ruschel* does extend beyond this fissure, which is therefore wholly enclosed within the crushed rock. Again the new make of ore on the Montana Mine on the north-eastern side of the *ruschel* occupies a fissure which certainly extends back in a southerly direction into the broken zone.

In the case of the narrower *ruscheln* the lodes sometimes actually cross them. Thus in the Oonah Mine the "north carbonate lode" crosses the slide without apparent deviation. In the Montana Mine, in the southern workings where the "No. 8 lode" junctions with the No. 2 slide at No. 8 level, the lode crosses the slide, and has been followed northwards for a few feet.

(*b*) Some of the lode-fissures make a very characteristic bend upon approaching the slides and actually follow the course of the slide for a short distance, sometimes passing out on the other side. In numerous places in the Montana Mine it is clear that a gradual bending—not a fracturing—of the lode-fissure has resulted.

The developmental work at the northern end of the stannite lode on the Oonah property shows this feature admirably.* And on this mine, also, the "main galena lode" makes the characteristic bend on approaching the slide, and then follows the course of the slide for some distance. Unlike the stannite lode, it has not yet been traced in the country on the northern side of the slide.

(*c*) In those cases in which intersections are visible the lode-fissures are not broken by the slides. Their direction may alter, and a single fissure may split into several smaller fissures; but each of these fissures is in itself continuous, and free from dislocation by the larger slides.

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* See Plate XI.

The materials filling the lode-fissures are uncrushed, and continue without interruption into the *ruscheln* in those cases in which the lode-fissures pass into the slides. Had the slides post-dated the lode-fissures and the period of lode-filling we should reasonably expect to find—at least in the immediate vicinity of the intersections of the two—a marked discontinuity of the fissures, and an equally prominent brecciation and redistribution of the lode-matter.

(c) *The Modification of the Later Fissures by the Pre-existing Fractures.*

Since the slides have clearly been formed prior to the lode-fissures, it remains to examine in what way their presence has affected the later fracturing. It has been found, by the examination of the workings of the mines now in operation, that different structural features result in different cases. There are even varying features presented at different points along the intersection of a slide with one and the same lode.

(1) *The "Bending" or "Drag."*—The most noticeable of the phenomena is the turn of the course (strike) of the lode-fissure as it approaches the slide. This bending is at first gradual, and increases with proximity to the slide until, in many cases, the lode-fissure becomes parallel to the boundary of the slide, and follows its course for some distance. This is shown to a notable degree by the northern end of the "main galena lode" on the Oonah Mine, and on a much smaller scale at many points north of the shaft at the Montana Mine, at the intersections of Nos. 2, 3, and 4 lodes with the main *ruschel.* Nevertheless this "drag," as the bending is called, is absent at some points, and the lode runs right up to the slide, and there ends abruptly.

(2) *The Splintering.*—Frequently it is found that the lode as it approaches the *ruschel* splits up into a number of stringers, which diverge as they approach the slide, so that the lode, as seen in plan, spreads out like a fan, with narrow wedges of country-rock between the stringers of lode-matter. Each of the stringers usually shows to some degree the "drag." In some cases one of the stringers may be seen to bend round till it follows the course of the slide, while other stringers actually penetrate for a short

distance into the *ruschel* itself. Examples of this splitting-up of the lodes near the slides are very common on the Montana Mine. The northern portion of the stannite lode on the Oonah Mine has apparently suffered a splitting-up, while that portion which lies to the southward of the slide is not splintered in the same way.

The splitting-up of the fissures is certainly due to the existence of the *ruscheln*. The strains developed in the country-rocks have produced fractures which have been on the whole fairly straight and clean for some considerable distance. In the region of the slide the country suffering the later deformation has been already greatly weakened by the formation of the *ruschel*, and the splintering of the fracture has resulted.

Since there may be seen in some cases actual displacement of the lines of fissuring with complementary "drags" on the two sides of a slide, *e.g.*, the Oonah stannite lode, while the general directions of the two portions of a lode-fissure remain fairly constant, it is probable that the stresses producing the lode-fissures have been to some extent torsional ones. The splintering of the fracture near the weakened *ruschel* zone would certainly be more readily produced by torsional than by other stresses.

(3) "*Dying-out.*"—In many cases it is apparent that a lode-fissure on reaching a slide "dies out" or terminates abruptly. In some of these cases there are crosscuts in the vicinity which serve to give definite proof of this termination. For instance, the eastern and western crosscuts from the Montana Main Shaft have shown that any northerly extensions of the lode-fissures which have been worked on the south-western side of the No. 2 slide are entirely insignificant. The lode-fissures may be said to practically cease at the slide. In other cases there has not been done enough prospecting to warrant any definite statement concerning the termination of the fissures. The recent discovery on the Montana Mine is clear proof of this. Reluctance had long been felt to prospect beyond the apparent northern limits of the lode-fissures at the footwall of the main *ruschel* on account of the want of faith in any extensions.

In those cases in which a lode or lodes appear to terminate on reaching the slide the question of the possible extension beyond the slide is one of great difficulty. There has yet been little work done on any mines which may serve as a guide upon which to plan prospecting operations; and the little that has been done may possibly afford a wrong impression unless caution is observed.

When there are, as on the Montana Mine, several lode-fissures close together, and all apparently terminating on coming in contact with one boundary of a *ruschel*, the question of the extension of each beyond the *ruschel* demands consideration. Since the lode-fissures are younger than the *ruschel*, as has been pointed out above, their extension on the further side of it does not necessarily follow in the same way as in the case of the dislocation of pre-existing lode-fissures by a fault-plane. Moreover, although the lode-fissures have resulted from the operation of earth-stresses which have probably been simultaneously developed over large areas, it is quite possible that very different results have been produced on the opposite sides of a weakened zone, especially where this is a broad one, as in the case of the "main slide" on the Montana Mine. So it is possible that the same forces which have produced several fissures on one side of a *ruschel* may cause the formation of a single fissure on the other side.

The probable effect of a *ruschel* upon a series of lode-fissures cannot yet be foretold for the Zeehan field, since no general law governing the occurrences can be framed on the amount of development work which has thus far been carried out. The matter is one which must be postponed, but all such facts as may assist towards the solution of the problem should be gathered together by the various managers who are confronted with the phenomena, and should be recorded on the mine plans.

It is therefore inadvisable, in the present state of our knowledge, to try and identify a lode on one side of a *ruschel* with one of a number on the other side. Thus in the case of the Montana Mine the new find on the northern side of the main *ruschel* cannot be yet stated to be either the No. 3, No. 2, or No. 4 lode which have been worked on the southern side. On the other hand, it is imperative to ascertain whether or no other lodes exist on the other side of the *ruschel*, and the matter can only be determined by prospecting.

(*d*) *The Relation of the Period of Lode-filling to the Periods of Earth-fracturing.*

There is no room to doubt but that the period of the introduction of the metallic ores followed after that of the formation of both main sets of fissures. Certain other small displacements of the lodes have taken place after their formation, but the significance of these is not great.

The ore may be traced along the lode-fissures right into the slides, where the latter have actually been penetrated by the later fracture-planes. And this ore is not different in any respect from that of the main portion of the lode-channels. The mineral composition is the same, and all traces of brecciation are absent, even when, as sometimes happens, the vein-matter runs along the edge of the *ruschel*.

Where a lode-fissure has been splintered it is found that the ore is distributed along the several small fissures, although the proportion of ore present in the several smaller fissures in each case differs.

As has been mentioned above there are certain ore-filled fissures which extend into the *ruscheln*. Others occur entirely within the boundaries of the *ruscheln*, and cannot be regarded as portions of fissures which traverse the uncrushed country. Yet even in these cases the metallic ores and their gangue minerals are uncrushed, while all the surrounding country-rock is comminuted and contorted. Too little work has been done to say whether or no these occurrences of ore have definite connection with the lodes outside the crushed zone. In some cases where they appear independent bodies on one level there may exist unrevealed connection in depth with the more continuous veins.

The dimensions of these makes of ore within the main *ruschel* of the Montana Mine are variable. The largest of them has been worked above the No. 5 and No. 4 levels. Many insignificant bodies were met with in the course of development work, but were not followed for any distance.

We may therefore safely conclude that there has been no deposition of ore before the period of the formation of the main sets of fractures. Inasmuch as there are two distinct periods of fissuring, and since the fissures of the second period penetrate those of the first, a complicated system of fractures was already in existence at the time of the introduction of the metallic ores. In the great majority of cases observed by us the ore-bodies filled the fissures of the second period, some few of these being actually wholly or partly enclosed within the rock shattered by the dislocations of the first period.

(e) *The Distribution of Ore with regard to the Two Sets of Fracture-systems.*

In reviewing the mode of distribution of the ore in the Montana Mine one is at once impressed with the manner in which the ore continually recurs at the intersections of the later fissures with the *ruscheln*.* The lode-fissures extend back for some distance from these points of intersection, and have been driven on in a number of instances. But the shoots of ore are for the most part found to occur in immediate proximity to the *ruscheln*, and on the footwall side of each of these main faults. These phenomena are clearly exhibited by the plan showing the position of the slides and the productive portions of the lodes. The presence of the newly-found ore-body north of the slide is clear proof that the existence of ore is not wholly dependent upon the occurrence of intersections of *ruscheln* with later fissures; but in most cases on the Montana Mine this is true.

The occurrence of ore at the intersections of lode-fissures and *ruscheln* is marked in two ways: (*a*) The actual bulk of the lode-matter is greater at these points; (*b*) the proportion of galena in the lode is commonly highest there, and diminishes as distance from the intersections increases.

There are known shoots of ore along the course of the fissures further away from the main slide on the Montana Mine, but the only feature of regularity that has been determined is the fact that "the ore makes under the slide."

Comparing the occurrences of ore at the Montana Mine with those of the Oonah, one is met by a certain similarity in the method of distribution. But there has not been so much ground developed in the latter mine, and the intersections of the lode-fissures with only one slide are exposed.

With regard to that portion of the stannite lode which is being worked on the south side of the slide, there is one noticeable point of difference from the occurrences of ore at places similarly situated with regard to the main slide on the Montana Mine. This difference lies in the lengthening of the ore-shoot with depth in the case of the Oonah, while it is found that on the Montana Mine the ore-shoots butting against the main slide have always decreased with depth. The differences between these two modes of occurrence serve to prove that the shortening of the stope length of the shoot with increased depth is not a general feature.

The reasons for the occurrences of ore at the intersections of the two sets of fissures are apparently to be based upon physical conditions. The stresses of the later period have induced fractures which have in many cases

* See Plate VI.

(as on the Montana Mine) been best defined at the points of their intersections with the slides. Along the intersection therefore there have been the best facilities for the ascent of the metalliferous solutions. The impregnation of the fissures has proceeded outwards from those channels in the lode-fissures which afforded the most ready passage to the mineralising solutions at the time when the lode-formation was in progress.

It does not appear to be possible to forecast the probable distribution of ore in these fissures in depth, since it appears to be mainly dependent upon the irregularities in the channel, and these are not governed by any rules yet recognisable.

The only mines accessible to us in which the ore-bodies are located at the intersections of fissures were the Montana and the Oonah. To what extent these conditions exist in the Western and Zeehan-Queen Mines we are unable to state, but all such attempts as may be made to work the mines in the future should be made with a full understanding of what has occurred on the Montana and Oonah Mines.

B.—STRUCTURAL FEATURES OF THE LODES OTHER THAN THOSE CONNECTED WITH THE RUSCHELN.

The lodes of the field present certain characters which cause them to assume at different points a slightly more complex structure than that possessed by simple "fissure-veins." There are a few cases where the lodes have split and the arms reunited, and a considerable mass of country has been included as a "horse" between the two branches of the lode. "The main galena lode" of the Oonah Mine is a case in point.

A rather uncommon phenomenon in lode-structure is that displayed by the stannite lode on the Oonah, which consists in places of a series of overlapping narrow lenses arranged *en échelon*, so that the whole lode is built up of alternating bands of vein-matter and country-rock. This probably results from the nature of the fissuring in the slate-rock, which is readily split. Instead of a single fissure on any one level a number of apparently separated small fissures have resulted, the strike of which crosses the general direction of fissuring at a small angle.* The

* Compare the occurrence of ore in the Lake View Consols Mine, Kalgoorlie. W.A., figured by Mr. T. A. Rickard in the Transactions A. Inst. M.E., Vol. XXXIII., 1903, p. 576. See Plate IV., Fig. ii.

fissure-producing force has caused the opening up of the slate in a number of parallel directions, and the total displacement of the wall-rocks by the several small splits is equivalent to that which would result from complete fracture across the grain. It is necessary that these small parallel component portions of the lode which are filled with entirely similar material should have been connected at the time of the lode-filling. The connection appears to have existed at a lower level.

A vertical section across the lodes of galena ore in the Montana Mine shows how variable is the width of the ore in any single lode. Looked at in cross-section the lode appears as a series of lenses, the dimensions of which vary considerably, while between successive lenses there is merely a track of the lode. The reason for this irregularity in width must be sought in the actual shape of the lode-fissure at the time of the filling. Certain portions of this channel would appear to have been open, while others have been almost closed during the period of migration of the mineralising solutions; and the result has been that the mass of the ore-body is variable from point to point. No rules governing the distribution of vein-matter in the lode-channels having been recognised, it has been found profitable in a number of cases on the Montana Mine to carry the stopes up on the course of the vein where the development drives have shown only the track of the lode-channel.

In the case of the large pyritic mass which is being worked by Mr. Bruce on the Oonah property there is an absence of definition of the walls along some portion of the lode, and masses of slate which have not been replaced by the metallic minerals remain enclosed within the limits of the ore-body. The absence of defined walls, and the enclosures of country-rock within the mass of the ore-body, are both characteristic of lodes in which, as in this case, the metasomatic replacement of the wall-rock has occurred during the processes of mineralisation.

(9)—The Influence of the Country-rock upon the Lodes and the Alteration of the Wall-rocks.

A.—Influence of Country.

There are several questions, which may be grouped under this heading, requiring some critical discussion. A fuller appreciation of the several points involved and of their real significance will, in our belief, make for the benefit of the future of the mining industry.

The properties of the country-rock may possibly be regarded as having either a chemical or a physical effect upon the lodes contained within them. The chemical and physical factors are here briefly considered apart.

Chemical Factors.

The most common belief which has lingered in the minds of the mining community in Zeehan, and which calls for discussion here, is that concerned with the supposed influence of the spilite upon the formation of the silver-lead lodes. This belief is no longer tenable now that some considerable amount of development work has been done. While it is true that the physical or structural features of the lodes in spilite are at certain points somewhat different from those of lodes in slate, it must be remembered that none of the lodes in the Zeehan field proper depend for their existence upon any rock with which they are found associated. The source of the metallic material is more remote, and the lodes certainly do not represent the concentrated metallic contents of the rocks in which they occur.

This hypothesis regarding the genesis of ore-bodies is exceedingly difficult to eradicate from the minds of mining men. It does not appear to us necessary to repeat the arguments which may be given to show the inefficacy of such a hypothesis to explain the facts of occurrence. The matter has been already treated fully by Mr. G. A. Waller, with special references to the Zeehan lodes, in his report of 1904.*

Even where faith in the creative influence of the spilite is denied we have found traces of its existence still lingering. An example of this occurred in the case of a lode filling a fault-fissure such that for a portion of its extent one wall is spilite and the other wall slate. When development work was carried to the point where the fissure extended beyond the spilite, and both walls were of slate, it was believed for a time that the lode had terminated. The progress of development work has recently led to the working of this lode in the slate country, but some uncertainty appears to be felt with regard to the continuity of the same lode because of the change in the character of one wall.

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* *Loc. cit.*, pp. 19-20.

We are of the opinion that the realisation of the general sequence of the several events leading up to the formation of the ore-bodies, and the appreciation of the necessary conditions for the accumulation of the different metallic ores in veins or lodes, would disperse the feeling of hesitation which has attended the prosecution of further development upon such an ore-body as that cited.

While it must be admitted that the immediate country-rock has had no formative influence upon the lode-filling, a certain reservation would at first sight appear to be necessary in the case of the contact metamorphic zone surrounding the granite of Heemskirk, and the types of lode-filling found within the boundaries of this zone. For at this point the distribution of distinctive ore-bodies seems to coincide with that of equally characteristic country-rocks. Yet upon closer investigation it becomes evident that the same rock contains different vein-types; that the peculiar alterations observable in the country-rocks containing the ore-bodies are due to external causes; that the introduction of the metallic ores results from causes intimately related to those which have produced the metamorphism of the rocks; and that ores representative of certain vein-types extend outwards beyond the contact metamorphic aureole into the rocks not visibly affected by the granitic invasion.

These are the principal features of the zone of contact metamorphism, and the chief difference between the phenomena exhibited by this zone and those displayed by the regions more distant from the granite *massif* is that the country-rocks which were, before the granitic irruption, sensibly identical throughout a considerable area have been in part affected by the igneous mass. Hence the apparent dependence of certain types of vein-matter upon the presence of certain wall-rocks is definitely contradicted when a critical examination is made of this particular area, and when the causes of the several phenomena and their chronological sequence are properly appreciated.

We pass on to the discussion of other phenomena. It was found that there is a current belief among the miners to the effect that the presence of abundant graphite in the wall-rock containing the lodes (in those cases in which the lodes occur in slate) is a most unfavourable sign. Elsewhere* will be found an expression of our belief that the presence of the graphite is, in some way not yet understood, connected with the processes of lode-formation.

* *Vide infra*, p. 94.

That is to say, the country-rock has received its graphite during the period of vein-formation, and the graphite could not therefore possess the power of influencing the deposition of ore for either the better or the worse. If there were two distinct periods in the process—firstly the deposition of graphite, and secondly the introduction of the metallic minerals—it might be that the presence of graphite would exert some influence. However, there is no evidence of the existence of any difference between the period of deposition of the graphite and that of the metallic minerals.

As the result of our own observations made during the inspection of the workings of the mines, we have come to the conclusion that graphite cannot be regarded as an unfavourable sign, inasmuch as it is often prominent on the walls of some of the most important shoots of ore.

However, it is at the same time noticeable that where a shoot of ore pinches out while the lode-channel continues, the graphitisation of the wall-rocks has proceeded along the ore-channel beyond the limits of the shoot. Under these circumstances, in the absence of ore, the attention is unduly attracted towards the graphitic contents of the rock, and hence a false impression of the significance of the phenomena of graphitisation has been created.

One other question which should here be briefly treated is that which is concerned with the tenor of the lodes traversing limestone. Popular belief in the power of limestone country to influence the silver contents of a lode for the worse is certainly strong in Zeehan. But it is difficult to ascertain details of the grounds upon which the belief is grounded.

The lodes traversing the limestone are sometimes low in silver values, just as some of the lodes traversing other rocks are. For the variability in the silver tenor of the lodes is most noticeable in all parts of the field, and immediately adjacent lodes traversing the same rocks may vary between wide limits. Thus in the Montana Mine alone the silver values of the ore from lodes known as No. 1, No. 2, No. 3, and No. 4 are respectively 124, 100, 80, and 89 ounces per ton. Unfortunately we are unable to give, for comparison with these figures, others dealing with lodes which occur in limestone. During our visit to the field no mining operations were being carried out upon any such lodes. All workings that exist on these lodes are only at very shallow levels, and it is by no means certain that the primary ore has been reached.

It is a matter of some importance to ascertain, if possible, whether the lode-matter is of primary origin, or whether it represents a secondary enrichment, or again whether it represents a partially oxidised and leached portion of the vein, when the silver tenor of a lode is being discussed. In limestone country a lode is particularly prone to oxidation and leaching on account of the tendency of such a rock to dissolve and afford ready means for the movement of meteoric water. The greater solubility of silver compounds will, in general, render such oxidised and leached ore relatively poor in silver, save when chlorides are present and ceraragyritic ores accumulate.

It is therefore possible that the shallow workings upon the lodes in limestone in Zeehan have been carried on in ore that has suffered some degree of impoverishment in silver.

Physical Factors.

It is, in another portion of this report* stated that we believe the ore-deposits of the Zeehan field to have a deep-seated origin, and to have been introduced in solution along certain fracture-planes. The direction of the course of these fracture-planes is such that different rocks are traversed by different fissures, or that one fissure traverses different rocks, or that a fissure has along its course one rock for one wall and another rock for the other wall. In such cases it is noticeable that the fracturing of the slate and the spilite varies with the rock. Whereas the fractures in the igneous rock are more or less clean breaks, those in the slate are usually more ragged and irregular, especially on one or other of the walls.† Where a fissure is found to separate spilite from slate, and where mineralisation has proceeded along the plane of separation, it is found that there is an impregnation of the slate outwards from the fissure, while the spilite wall of the fissure remains clean and unbroken.‡ Hence it may be stated as a rule, of general application only, that lodes in spilite are narrower, and that their contents are more compactly aggregated than is the case in slate country. These features are due almost entirely to the behaviour of the different rocks when they have been ruptured by external forces, and the mineralising solutions have merely followed the course of the fissures already made.

* *Vide infra*, p. 99. † See Plate IV., Fig. iii. ‡ See Plate IV., Fig. iv.

B.—THE ALTERATION OF THE WALL-ROCKS OF THE LODES.

There is on the whole very little sign of alteration in the wall-rocks encasing the lodes of the Zeehan field proper. Farther to the westward, at Heemskirk, the tin lodes in the granite occur in country-rock that is sometimes highly altered. In the contact metamorphic aureole the metallic minerals are accompanied by a peculiar group of lime-bearing minerals, but these do not appear, as elsewhere stated,* to be merely results of the alteration of the immediately adjacent country-rocks.

In the transmetamorphic zone there is certainly very little visible alteration. The numerous mine workings in this zone afford excellent exposures for examination, and it may confidently be asserted that no material alteration has been effected.

Where the lodes traverse the spilite it is difficult to judge the effect of the mineralising solutions, for the rock was already altered at the time of the introduction of the vein-filling.

The one noticeable feature is the development of graphite on the walls of the lodes filled with different vein-types wherever these lodes traverse the slate country.† The restriction of the graphite to the immediate vicinity of the lodes, in spite of the fact that it is only to be observed in slate country, leads us to believe that it is of inorganic origin, and a product of the mineralising processes.

Beside the graphite, there is present at one place, viz., in the hanging-wall of Bradshaw's lode (which is worked by Mr. Bruce) on the Oonah property, a curious lustrous black mineral, which appears to be a hydrocarbon. With it, perhaps, may be compared the "anthracite" or "mineral coal" recorded by Ulrich as present in the North Valley Lead Mine, Mt. Bischoff;‡ and the hydrocarbon found in association with the auriferous quartz reefs of Beaconsfield, and recorded by Mr. A. Montgomery.§

Similar material is found with the tourmaline, cassiterite, and pyrite ore of Mayne's Tin Mine between Zeehan and Trial Harbour, and although a hydrocarbon, the origin

* *Vide supra*, p. 25.

† Compare the observations recorded in the Mt. Farrell Mining Field, Geol. Surv. Tas. Bulletin, No. 3, p. 59.

‡ See W. F. Petterd, "Catalogue of the Minerals of Tasmania," 1910, pp. 51–52.

§ *Ibidem*, p. 52. Also, A. Montgomery, "Report on the Geological Structure of the Beaconsfield Goldfield," 1891.

of which is commonly thought to be the destructive distillation of organic remains, the material may possibly be regarded as an inorganic deposit from metalliferous solutions.

In the Zeehan-Montana No. 2 Mine, in the neighbourhood of the No. 2 lode, there are a number of small galena-bearing veins on either side of which the slate is sericitised to a marked degree.* And the sericitic or pinitic mineral aggregate is also developed in the joints and crevices of the slate on the eastern side of the No. 2 lode itself. This is the only locality at which the development of sericite was noticed.

(10)—The Vertical Range over which Silver-lead Ore has been worked.

When we examine the topography of Zeehan it appears that the highest outcrop of a lode which has been worked for silver-lead ore is a little over 1100 feet above sea-level. The deepest mine workings have penetrated to a depth of about 300 feet below sea-level. Thus the extreme range of the workings is only 1400 feet when the whole of the Zeehan field is taken into consideration. The range in the deepest mine (Zeehan-Western) is but 1000 feet, and the development work which has been carried out at that level is very small. In the great number of cases the mining operations have been carried on over a much smaller vertical range than this.

The vertical distance over which we were able to make an examination of the variations in the character of the lode-filling was therefore a small one, and was lessened to a great degree by the inacessibility of a number of the mines. Nevertheless the workings to which we had access afforded unmistakable evidence bearing upon the matters here set forth.

In the discussion of the problems connected with the variation of ores in depth it must be remembered that the depths yet attained in the Zeehan field are wholly insignificant when compared with those at which silver-lead mining has been carried on in other parts of the world. For instance, the silver-lead mines of Coeur d'Alene district, Idaho, U.S.A., taken together, have a vertical range of over 4000 feet.† In Freiberg certain of the pyritic lodes

* Compare the observations recorded in the Mt. Farrell Mining Field, *loc. cit., supra*. pp. 59-60.

† *Vide* Professional Paper 62, U.S.A. Geol. Survey, 1908, p. 130.

have proved workable to a depth of over 2000 feet;* and in the case of the Przibram lodes, in Central Bohemia, the great depth of over 3500 feet has been attained. In the latter case the composition of at least some of the veins correspond to that of the siderite-galena veins of Zeehan.† At Foxdale, in the Isle of Man, and at Linares, in Spain, workings have been carried down as far as 1600 feet. The lead mines of Kuttenberg, in Bohemia, attain a depth of 2000 feet. These have recently been abandoned, after being worked for 700 years. The Kaiser Wilhelm shaft at Burgstädt, in the Upper Hartz, has been sunk 865 metres.

(11).—Comparison between the Occurrence of Silver-lead Ore in Zeehan and that of other Fields.

While the actual mineralogical associations of the argentiferous galena at Zeehan are precisely those which recur as well-marked vein-types in many parts of the world, it is furthermore possible to draw a close analogy between the general geological conditions existing at Zeehan and those of at least one fully described district.

The recent investigation of the ore-deposits of the Coeur d'Alene district, Idaho, U.S.A., by Messrs. Ransome and Calkins‡ has shown that there is an almost complete parallelism between the occurrences in that district and those in the Zeehan field. The similar ores are in both cases attributed to the presence of igneous rocks. In Coeur d'Alene the igneous outcrops are of monzonite; in Zeehan, of granite. In both cases the visible outcrops of the plutonic rocks are small when compared with the areas which would be covered by them if the progress of weathering had removed the overlying rocks to the depth of a few thousand feet. (Zeehan, of course, after such erosion would be submerged beneath sea-level.) The Coeur d'Alene ores are developed in a region which rests in part upon the main Idaho batholith, just as the Zeehan district rests upon the main West Coast batholith. The observed outcrops of the Coeur d'Alene monzonite are surrounded by contact zones which carry ores identical in character with those of the Comstock district. And ore of this char-

* R. Beck, "The Nature of Ore-deposits" (Weed's translation), Vol. I., p. 238.

† *Ibidem*, pp. 253-256.

‡ *Loc. cit., supra*, pp. 134-140.

acter in both districts gradually merges into the siderite-galena type as the igneous rocks become more distant.

The fuller comparison between the mode of occurrence of the ore-bodies of the Zeehan field and those of other fields will serve no useful purpose.* It is sufficient to state that, as far as general geological relationships are concerned, essentially identical conditions may be shown to exist in other areas.

Nor are the minor structural features of the Zeehan lodes without parallel in other mining fields. For instance, the *ruscheln* have been recorded from St. Andreasberg. But these structural features have no genetic significance; they are merely the accidents of environment.

(12)—Summary of the Genesis of the Zeehan Lodes.

The following is a condensed statement of the geological history of the Zeehan lodes:—

A.—The Invasion of the Igneous Magma in Devonian Times.

At the close of the Silurian epoch of sedimentation this portion of Western Tasmania was occupied by a complex series of sedimentary and igneous rocks. The region had suffered some considerable degree of folding and fracturing in Pre-Silurian time, and at the time of the subsequent invasion of igneous material the structure was already complex. The Silurian sediments were laid down upon foundations which consisted of faulted and tilted blocks of the older rocks.

The igneous invasion which followed closely upon the period of the accumulation of the Silurian sediments affected a very large proportion of the whole of Tasmania. Subsequent prolonged erosion removed so much of the upper portion of the crust that the deep-seated consolidation products of this magma were exposed at the surface in Permo-Carboniferous time, and are now also exposed at the surface in many places. Thus we are unaware whether the igneous rocks actually extended upwards to the surface at the time of their upward movement. In the West Coast region, as in other portions of Tasmania, we are concerned only with the plutonic consolidation products and apophyses therefrom.

* Mr. G. A. Waller has drawn a comparison between the lodes of Zeehan and those of Freiberg in his report on the Zeehan field, to which reference should be made. *Loc. cit.*, pp. 25-26.

The igneous rocks which have resulted from the cooling of this magma vary between somewhat wide limits. The earliest rocks to consolidate are of basic composition. These have been altered by the slightly later invasion of the granite, which in the neighbourhood of Zeehan greatly exceeds the basic rocks in bulk. The apophyses from the granitic magma have penetrated the surrounding rocks to some considerable distance from the actual granite.

The nearest granite to Zeehan is that which constitutes the *massif* of Mt. Heemskirk, the exposed eastern border of which approaches to within 5 miles of Zeehan. This granite has round its margin a development of basic rocks—gabbro-amphibolite and serpentine. To the east of Zeehan, in the neighbourhood of Dundas, Five-mile, and North Dundas, rocks of similar origin outcrop. The relative age of the acidic and basic varieties in this district is identical with that of the Heemskirk rocks; but near Dundas the basic varieties largely preponderate over the acidic ones in bulk. There are also similar rocks to the north of Zeehan at the Meredith Range.

Since, therefore, the Zeehan field is surrounded by outcrops of plutonic igneous rocks, and is penetrated at various points by dykes which are certainly related to them, it must be granted that the magma whence these rocks were derived once extended continuously at some unknown depth beneath Zeehan itself. The consolidation products of this magma would form continuous areas of igneous rocks if the superincumbent rocks were removed. The actual igneous outcrops are situated at those points at which the magma attained its greatest elevation during its ascent into the upper regions of the earth's crust, and the extent of the outcrops at the present time has been determined by the sum total of the effects of cycles of erosion which followed the igneous invasion.

B.—THE PERIOD OF FORMATION OF THE PRIMARY ORES.

The metallic ores of Zeehan have been traced westwards through a series of gradually-changing types as far as the granite, and even at some points to places within the granite borders. Here actual observation is brought to an end, and in further searching for the proximate source of the ores we are forced to rely upon the inferences that may be drawn from a comparison between the general geology of this district and that of other neighbouring mineral fields. We find that the Zeehan ore-bodies penetrate the rocks older than the granite, and the granite itself; but we do not know of any Tasmanian example of an ore-body, related in any respect to the Zeehan ores, occurring in post-granitic rocks. We therefore conclude that the period of formation of the Zeehan ores followed immediately after the period of consolidation of the granite.

The continual recurrence of metallic ores with the Devonian granitic rocks in both the West Coast and other portions of Tasmania affords undeniable evidence in support of the belief that the granite and the metallic minerals are both derivatives from one magma. The order of their derivation from the magma has already been indicated. The progress of consolidation has been coincident with a concentration in the heart of the magma of certain of the ingredients once distributed throughout its mass. The crystallisation of the non-metallic minerals round the cooling borders has caused the movement of the remaining constituents towards the centre. The aqueous content of the original magma, aided by the presence of "mineralising agents," carbonic acid, fluorine, and boron, has at this period gathered together the scattered metallic contents, and formed an intramagmatic concentration of them.

In the latest stages of consolidation a considerable proportion of this material was expelled forcibly from the magma hearth. It rose along fissures which traversed the already partly-cooled outer crust of granite (possibly contraction cracks consequent upon the cooling), and which were connected with others extending far beyond the igneous boundaries in the superincumbent rocks.

The precipitation of the metallic ores took place in these fissures at such points at which the necessary physical conditions of temperature and pressure obtained. The dissolved metals were precipitated in such a manner that different mineral combinations were formed at different points during the outward passage of the metalliferous solutions. The roots of the lodes extend downwards through the granite while the upper portions extend far above the contact of the granite and intruded rocks.

These final stages in the consolidation of the igneous magma of Devonian age marked the cessation of the period of deposition of the primary ores of Zeehan.

C.—EVENTS SUBSEQUENT TO THE FORMATION OF THE PRIMARY ORES.

The precipitation of the metallic ores in and around Zeehan took place at a time when the rocks now at the surface were comparatively deeply seated. Following after the period of ore-deposition there have been at least two epochs of denudation of which there remains geological evidence.

The first of these appears to have immediately succeeded the Devonian irruption. The invasion has apparently taken place at a time when this portion of Tasmania was being raised above the level of the sea, in which sediments of Silurian age had been deposited. The area must have remained exposed to the action of denudation for an exceedingly long time, inasmuch as the granite itself was laid bare by the time when a positive movement of the strand line once more brought about submergence beneath the sea. During this long period of erosion it is quite probable that the ore-bodies, as well as their enclosing rocks, suffered some diminution in bulk.

But at the beginning of Permo-Carboniferous time marine conditions were restored, and continued from that period onwards to the close of the Mesozoic. During this long interval of time sedimentation was proceeding, and the ore-bodies were being covered by an ever-increasing protecting cover of aqueous deposits; for these deposits very probably extended right over Zeehan, although few traces now remain of their former existence. The diabase sills intercalated with these sediments may also have extended westwards from Mt. Dundas across the Zeehan field.

However, at the close of the Mesozoic era there was a marked retreat of the sea, and it is probable that the western margin of Tasmania was affected by the faulting which is more evident upon the northern and eastern sides of the island.

Almost every trace of these earth movements has been removed by the erosion which has proceeded continously since the close of the Mesozoic era. The Permo-Carboniferous and Mesozoic rocks have been practically entirely eroded away, and the subjacent rocks have been once more attacked. In the later stages of this latter cycle of erosion, which is still operative, the upper portions of the ore-bodies have undoubtedly been removed. The rate of degradation has been rapid enough to prevent the accumulation of any considerable bodies of oxidised ore. In fact, in the case of the great majority of the lodes the complete absence of an oxidised capping is a most noticeable feature.

H. W. Judd, Photo.

THE ZEEHAN-MONTANA NO. 1 MINE AND MILL

VII.—MINING PROPERTIES.

This report is not intended to include descriptions of the underground workings of the mines on the Zeehan field, its aim being rather in the nature of an investigation of lode characteristics. Nevertheless in the course of the examination developments underground have been visited, and the following memoranda of the visits to particular mines comprise the salient features which are more or less pertinent to the inquiry.

The mines which we visited are situate in the siderite belt, the pyrite belt, and the contact-metamorphic belt respectively, and their lodes fall into one or other of the classes severally appropriate to these zones.

In the siderite belt are situate the mines Zeehan-Montana No. 1, Western, Mt. Zeehan (Tasmania), Victoria-Zeehan, Nubeena, South Nubeena, Central Balstrup, Sunrise, Kemp's, Marsh's, Stevenson's.

In the pyritic belt are the Oonah, Clark's lode, Cornish and Prairie's tribute, Clark and party, Montana No. 2, Barnett's, A. D. Sligo's, Susannite, Colonel North, Swansea, Stonehenge and T.L.E., South Comstock, McDermott's, Bailey's tribute, Simpson's.

In the contact-metamorphic belt are the Tenth Legion, Silver Stream, and Blende Show, near Trial Harbour-road.

A few other minor developments were visited by us which are located in one or other of the above zones; and there are several other mines, once important, but now closed down, and not accessible.

(1).—The Sideritic Belt.

Zeehan-Montana Mine.

Eight mineral leases are charted as comprising this property, viz., 1666-M, 80 acres; 243-87M, 80 acres; 1636-M, 58 acres; 2154-87M, 62 acres; 736-87M, 40 acres; 201-87M, 40 acres; 199-87M, 40 acres; and 691-M, 22 acres. These have now been consolidated into a lease of 422 acres, No. 3990-M.

This mine is next to the Zeehan-Western, the deepest mine in Zeehan, the main shaft having been carried down to a depth of 800 feet from surface. The Western Mine, which adjoins it on the north-west, has a shaft sunk to 1000 feet, but the mouth of the Montana shaft is about 75 feet lower than that of its northern neighbour.

Eight levels have been opened out from the Montana main shaft, and the mine has been a continuous producer of good-grade silver-lead ore since 1893.

The following figures, kindly supplied by Mr. Jno. Craze, the general manager, embrace the output from the company's mine from 1893 to the end of 1908. From 1904 onwards some of this ore came from the Montana No. 2 Mine. In 1909 about 3000 tons galena were produced :—

Year.	Output				Average Assay Value.			
	Ore Raised. Firsts.	Ore Raised. Seconds.	Ore Milled.	Concentrates.	Prill Ore.		Concentrates.	
	tons. cwt.	tons. cwt.	tons. cwt.	tons. cwt.	Lead. per cent.	Silver. oz. per ton.	Lead. per cent.	Silver. oz. per ton.
			Argent Mill.					
1893	182 12	150 0	...	...	66·5	120·2		
1894	1118 13	1820 9	1967 15	247 10	66·4	113·1	76·2	97·6
1895	1333 9	3398 0	3198 5	355 2	64·1	110·9	74·8	89·2
1896	1479 10	5821 0	6086 2	739 1	64·0	97·3	71·5	90·4
			7811 16	834 11				
			Montana Mill.					
1897	1982 0	10,000 0	899 11	100 3	64·5	100·3	67·6	84·0
1898	1675 17	15,375 0	16,196 0	1678 4	62·5	99·6	65·6	83·7
1899	1686 10	16,070 0	16,450 0	1648 0	64·1	105·4	59·8	77·8
1900	1637 0	16,490 0	16,515 0	1664 0	63·6	97·7	63·2	77·7
1901	1798 0	18,923 0	18,923 0	1995 0	64·2	101·7	63·8	80·6
1902	1832 0	20,542 0	20,542 0	2091 0	65·5	100·9	65·2	82·4
1903	1940 0	17,219 0	17,453 0	1690 5	65·6	99·3	66·2	69·4
1904	1540 5	13,389 0	16,853 0	1916 8	66·4	93·6	65·4	72·3
1905	1641 13	12,006 0	15,163 0	1596 3	65·4	92·1	63·0	68·6
1906	2223 1	12,754 0	15,687 0	1932 2	69·5	91·2	62·3	67·8
1907	1491 0	12,512 0	16,813 0	1816 2	69·1	85·8	64·3	67·6
1908	1264 0	13,386 0	13,386 0	1375 13	63·9	90·3	63·8	74·7

NOTE.– The ore milled is not entirely from the No. 1 shaft, some being from No. 2 and No. 3 shafts. Before 1904 almost all the ore shown in the table was won from No. 1 shaft.

The disquietening circumstance about the work is that an impoverishment of the lodes has been experienced from the 500-feet level downwards, the ore-shoots shortening and yielding only small quantities of ore below that horizon. The mine is one in which the distribution of the ore is conditioned by strongly-pronounced geological factors, and these must be understood if it is desired to gain an intelligent idea of what should be the guiding principles in the development of the mine.

Several lodes have been worked: the miles of exploratory and other drives, and the complicated nature, as well as the extent, of the underground workings make it far from easy to acquire a comprehensive and yet accurate idea of the mine as a whole, and its varied problems in particular. Without the assistance received from the manager and the gentlemen whom he put at our disposal our task would have been very difficult and tedious.

The country-rock enclosing the lodes consists of slate, with occasional beds of quartzite and micaceous sandstone, the whole accompanied by contemporaneous beds of tuff and vesicular lava (spilite). The latter, however, is sometimes plainly intrusive—see the dyke traversing the slate in the face of the cutting opposite the Montana mill. At undisturbed points the strata strike west of north, and dip east of north. Broadly, this area is one of spilite and spilite tuffs situated to the north of the tuffaceous slate zone of the Comstock tramway. These two belts of country belong, we are inclined to believe, to one and the same geological system, but which was earlier and which was later, or whether both were isochronous, must remain for the present unsettled.

The strata in the mine are disturbed by three or four principal faults (or slides as they are called locally). Some minor faults have dislocated the lodes, but have produced no far-reaching effects. The lodes are north-and-south ore-channels, which become payable as they approach their intersections with the main faults.

The principal slide (No. 1) in the Montana Mine is a belt of disturbed and crushed slate descending in a wedge-like form, being 200 feet wide at surface, and contracting to about 100 feet at 500 feet below the surface. Lower than this it has not been passed through. It has a well-defined footwall, but the hanging-wall is not at all well marked, and in that direction the crushed and distorted material tends to become gradually less broken, and finally merges into undisturbed strata. The direction of the slide is north-west, and its dip north-east. Its composition is distorted and broken slate, with stringers and patches of quartz and carbonate of iron.

As the lodes approach the footwall of the slide, they split and branch, and these branches curve round till they abut against the wall of the slide. As a rule they do not penetrate into the crush zone, and any ore which is found within the slide is in the form of irregular concentrations rather than lode continuations.

The branches just mentioned are the favourite repositories of ore; but the shoots have shortened in descending. At No. 5 level the ore was patchy, and the stopes lower than this level were practically unpayable.

At No. 5 level the lode strikes the main slide at a wide angle. The vein-fissures seem to be confined to the footwall country below the slide. At No. 6 level the junction of No. 4 lode with the slide is obscured by timber, but a little galena makes as the slide footwall. This level passes through the slide, inside the hanging-wall of which are bunches of carbonate of iron and galena. At No. 7 level in the stope behind the end, and some 15 feet south of the slide, the lode is splintered or branched, and the carbonate of iron filling makes in the direction of the usual drag towards the footwall. The filling ends with a swell, but the lode track continues with the drag.

No. 8 level on No. 6 lode has been driven a long distance, but only one bit of galena was found. The drive north is in short-jointed rock, with no regular cleavage. The dark slates of the country run parallel with the lode-channel. Tongues of carbonate of iron branch back into the hanging-wall country (W.). The country shows continual changes from vertical to flat beds. The lode has been followed with a soft selvage, showing frequently carbonate of iron. The level seems to be all the way in a slaty crush zone containing quartz and carbonate of iron. The crushed material pinches now and again into a strip of a couple of inches in width, and then widens out to a few feet. At certain points along this broken zone water trickles through rather plentifully. A good distance has to be driven yet before the slide can be reached, and as the lode-filling in the levels above did not go back a great deal from the slide, ore can hardly be expected yet, even if it makes at all on this level. It is to be noted that the carbonate of iron gangue has persisted down to the bottom level, and there is very little pyrite in the lode track at No. 8.

At this level near the shaft No. 8 lode, or a portion of it forming a very narrow track, has been followed in the drive. The end is in crushed slate with veins of quartz and carbonate of iron. The lode so far has been worthless. A crosscut has been put out from the end to prove the country, but only passes through alternate beds of slate and fine-grained grey quartzite.

Going south on No. 8 lode at the same level only an iron-stained track is at first followed, but this opens out to a couple of feet of carbonate of iron which forms a swelling in the lode. This becomes more massive, with crystalline siderite and what seemed to be blende. Further south galena makes first on one wall and then on the other. The country is slate, of a somewhat altered nature. Heads appear in the drive, and makes of iron carbonate form a kind of herring-bone lode with spurs. A crosscut has been driven back north on a spur of carbonate of iron at a point where on No. 7 level there was a horse. Continuing further south, the fork of the main split is reached. The stopes hardly paid above this, but improved as they went up. The other split is the better drive. This will probably unite with the main lode, as it did at No. 7 level.

It is plain that the lower workings of this mine are in a zone of the lode which is poorer than its upper portions. The lowest level has not yet advanced far enough north to prove whether any change for the better exists in the vicinity of the main slide.

As long as the lodes were considered as being cut off or heaved by the slide to unknown distances, not much hope existed of recovering the supposed missing portions on the north side of the fault. But the evidence is in favour of the contention that though the country has been faulted, the lode-fractures had no existence prior to the slide, and the ore-veins have either terminated at or in the fault, or have deviated along it to emerge on its northern side at points which may not be exactly opposite to where they abut against its southern wall.

At all events, a lode has been recently picked up north of the slide on Nos. 3, 4, and 5 levels, supporting our view that the structural geology of this fault and lode-system favours the existence of lode-channels on the north side no less than on the south.

The No. 2 slide in this mine would appear to junction with No. 1 slide at some place in the north-west workings, but the actual junction has not been observed. Its width is only a few feet—1½ to 3 feet. It is responsible for the ore-shoot south of the shaft, descending almost to No. 8 level.

The No. 3 slide is wider than No. 2, namely, 30 feet of broken ground exists below it, and the ore makes, as usual, in the footwall country.

No. 4 slide differs from the others in dipping south-west.

No one can pay much attention to the features of the Montana lodes without being led irresistibly to the conclusion that the slides are the controllers of ore-deposition. In any exploratory programme this must be, and we have no doubt is being, borne in mind.

The work which is now being carried on north of the main slide is well designed to reach successive shoots of ore in that direction, and it is hardly possible to overestimate its importance, for, apart from deeper sinking, it is in that direction that the future of the mine may be said to lie.

The most significant of recent discoveries in this mine has been that of the ore-shoot north of the main slide at Nos. 4, 5, and 6 levels, proving absolutely that ore-deposition is not restricted to fissures south of this fault. Mr. Jno. Craze, general manager, has furnished us with the following statement of the work done on this shoot since we were on the field. He says:—

"The shoot was first intersected at No. 3 level; then at No. 4 level; and, later, at No. 5 level. Drives were driven at No. 6 level. Here the lode, when found and driven on, was composed of carbonate of iron and zinc blende. The zinc appeared to replace the galena, as it was distributed throughout the iron in a similar manner as the galena showed in the iron at No. 5 level. A rise put upon the lode from No. 6 to No. 5 level, and an intermediate drive driven 40 feet below No. 5 level off this rise, together with the continuation of the drive at No. 6 level 100 feet north of the ore-shoot, proved that the lode contained no galena below 40 feet below No. 5 level.

"East crosscut, No. 3 level north of shaft: This crosscut has been extended 150 feet, but there was no sign of any lode. The crosscut has been discontinued, and a crosscut started from the end of No. 4 lode, No. 1 level, driving west. The country-rock north of the slide here is the locally-named 'white rock.' The crosscut is being driven westerly, and is now 40 feet west of No. 4 level.

"North drive, No. 2 lode, No. 3 level: This is the drive where the ore was first intersected north of the slide. At a point 20 feet north of the ore a second slide of small dimensions crossed the formation, and cut off the lode. This drive has been driven further north about 200 feet from the end of the ore first cut. We have intersected a new shoot of ore here, and have driven about 40 feet on it. The ore started as a small stringer, some days showing a little ore, others none, but for the last 20 feet the lode has been gradually widening, and now shows 4 feet wide—2 feet of clean galena. An assay of a picked sample gave 67 per cent. lead and 115 oz. silver. This shoot is behind a new slide, which we have not yet been able to locate at the lower level."

A great deal of interest necessarily attaches to the question of what character the lode will prove to be at depths lower than that reached in this mine. The assertion that because shoots of ore in the upper parts of the lodes have thinned out, it may be taken as certain that ore-deposition was confined to that horizon in the lode-channels, and consequently deeper exploration is waste of money, rests on no evidence worth considering.

Metalliferous solutions, having their origin in a deep-seated source, have been conveyed through ascending conduits thousands of feet in length, and it is inconceivable that the precipitation of their contents should bear any uniform relation to the purely fortuitous plane of the present surface of the ground.

Shoots of ore as a matter of common experience in mining succeed one another at various vertical distances in lodes, and the termination of one shoot is absolutely no indication that another does not exist lower down. Especially is such an inference excluded if no change is observable in the structure of the lode-fissure and the nature of its gangue. In the Montana Mine the lode-channels and the primary carbonate of iron gangue persist downwards to the lowest level reached, and show no indication of any impending change. The silver ratio, too, is practically constant, and does not support any theory of the mine workings in descending having passed out of and below a superficial zone of secondary enrichment. The main slide remains the permanent factor which has to be considered in connection with exploration for ore-shoots. There is no sign that this will prove a merely superficial feature. While it continues to descend, there will always be a likelihood of ore-shoots recurring in its vicinity.

At what depth ore-shoots may be expected to reappear in the lodes is beyond human power to indicate. The utmost that we can do is to show the solid grounds on which the expectation rests that they will recur sooner or later. The mine workings have reached a horizon below which a search for new shoots will have to be initiated, and the usual risk will have to be taken.

Zeehan-Western Mine.

This is the well-known mine north of and adjoining the Zeehan-Montana, and which for a long time put out large quantities of silver-lead ore with profit to its owners. The shaft has been sunk to 1000 feet in depth, the last 200 feet with the assistance of the Government, but owing to the decreasing size and unpayable nature of the lodes at the lower levels, the present company decided not to continue sinking unless further State aid could be assured. The deep levels are now full of water, and consequently we could not examine them. Our information respecting the deep mine workings is derived from Mr. J. Craze, the general manager. Mr. G. A. Waller reported on the mine down to the 600-feet level. Mr. Craze informs us that between the 400-feet and 700-feet levels the lode dwindled to a mere track, but opens out again at 800 feet, where it averages 4 feet in width for 1000 feet in length. In the middle of it at 250 feet south of the shaft a bunch of ore was struck carrying 110 oz. silver per ton and 68 per cent. lead. This shoot, however, had a length only of 25 feet. A winze was sunk below it to 80 feet, and 1½ cwt. of good fahl-ore was found. At the 1000-feet level three lodes were intersected, the first two (which forked at 800 feet) being 12 feet apart, and the third at the end of the cross-cut was a vein 2 inches wide, which carried a little galena assaying 50 per cent. lead and 50 oz. silver per ton.

The practical giving out of the ore below the 300-feet level is the serious feature of the main lode. Our inability to get into the low levels is regrettable. Under the circumstances we do not feel that we can offer any remarks that would be likely to be of use.

Mount Zeehan (Tasmania) Silver-lead Mines (No. 3728, 584 *acres).*

This large property is held by an English company on a consolidated lease, and embraces certain sections belonging at one time to the Argent, Silver Queen, Silver Queen Extended, Balstrup's, Spray, and Britannia companies. The principal work recently in progress has been on the Argent Flat and the Spray Hill.

The company's original capital was devoted to the development of the sections previously owned by the Argent and Silver Queen Extended companies, which at first, though giving ore returns, were not exactly remunerative. Subsequently tributors worked the blocks at shallow depths, and maintained a fair output. Finally, the Queen Extended and the Silver Spray lodes began to yield good returns, and the latter lode has continued to reward the company with a splendid output until very recently.

Quite a number of lodes traverse the property in the Argent Flat, mostly striking in a north-westerly direction. There is another group of lodes striking north or north-easterly. A good deal of ore has been won at one time or another from rich shoots in these lodes, but no really deep work has been carried out. Tributors have worked several of them in the shallow levels for many years with a fair measure of success, and it is a reasonable supposition that if followed down the numerous lode-intersections will show valuable concentrations of ore.

At the time of our visit the company was sinking a new prospecting shaft in the flat on some siderite-quartz veins, with fahl-ore, galena, and chalcopyrite.

Spray Mine.—This has rewarded the company with a large output of high-grade antimonial and galena ore. A belt of country about 9 chains in width contains four or five parallel lodes, the most important of which are No. 1 and No. 3. No. 1 is the main Spray lode, and No. 3 is called Gurnie's lode. A main shaft has been sunk to a depth of 450 feet, and six levels driven. Nos. 1 and 2 levels are above the shaft. Owing to the unpayable nature of the lode in the lower workings work had been given up prior to our visit, and the levels from the shaft were inaccessible. We could only enter the main adit-level, which has been driven south-west for 1100 feet, cutting Nos. 1, 2, 4, and 3 lodes successively.

We examined the level on No. 1 lode for a certain distance only owing to it being blocked by a fall, but we understand that no ore has been won from the lode above this, while at the level below ore has been stoped a length of 600 feet.

Lodes Nos. 2 and 4 proved to be unimportant, but No. 3 (Gurnie's) has been driven on north for several hundred feet, and was payable for a long distance in this direction. Its outcrop appears at the top of the Spray Hill, where its gossan was found to be rich in silver chloride and native silver, and was worked down from surface by the discoverer and tributors. At the adit level the southward extension of this lode towards the section boundary has split, and the west branch has again divided. The lode-channel in the ends shows little or no ore, and is itself ill-defined. This is the lode-line through a mineralised and fissured zone of country which continues to the south through the Victoria-Zeehan and Nubeena sections, carrying ore at intervals in some of its channels. The northern drive in this level was continued to a point about 2000 feet distant from the mouth of the adit, and the lode in the face does not show more than a parting between slate and quartzite. Veinlets of quartz in the latter appear to have orginated prior to the lode, and to have no connection with it.

The ore-bearing part of this lode consisted of a series of lenticular bunches, about 2 feet wide, and appearing and disappearing successively. These were followed down to some depth, and are said to be absent from the bottom level.

For the information relating to the lower levels we are indebted to the general manager, Mr. T. Vincent. We gather that the lode-channel continues down to the lowest level (450 feet below the shaft mouth), but that the lode at that depth is not payable where driven on. Some high assays were frequently obtained, but there was no quantity of this ore. Three stopes were taken for 70 feet over the level, and some rich ore was picked out, but as a whole the lode did not pay to work. The manager states that a small hole was sunk to 10 feet below the floor of this level, showing a lode-channel filled with slate and carbonate of iron with a small patch of galena at the start 6 inches wide.

The ore in the upper levels has been won from what show in sectional plan as irregular, disconnected blocks or ore-bodies. Viewed broadly, however, these are probably parts of one ore-body of varying value, and in our opinion no adequate reason can be adduced for not considering the lodestuff in the bottom level as a low-grade part of the shoot. The depth attained is altogether too insignificant to justify any one in believing that deep mining has exhausted the possibilities of this magnificent lode. The ore obtained at this depth has returned 5 per cent. lead and 30 oz. silver per ton. The silver contents are dependent upon the proportion of antimonial ore: one sample assayed 1100 oz. A small parcel was broken out, yielding 16·3 per cent. lead and 425 oz. silver per ton. The fact of the lode-channel going down unimpaired and rich ore occurring, however sporadically, must be regarded as warranting further and deeper exploration.

This company has carried out very extensive exploration at a comparatively shallow depth, and with good results. It remains now for it to open out a new mine below its old one. At all events it appears to us inadmissible to conceive of the 450-feet level as marking the lower limit of ore-deposition.

Further sinking of the Spray shaft is necessary to explore the lode at a greater depth, and a complete scheme for proving the company's property would in our opinion include the putting down of a main shaft in a central position on the Argent Flat, from which deep crosscuts could be driven to intersect many of the ore-producing veins which are seen at surface. There is every likelihood of some of these uniting in depth and forming larger ore-channels.

One very striking feature on this property is the large gossan outcrop on Manganese Hill. The strata composing this hill belong to the Cambro-Ordovician slate-tuff series, and a wide surface outcrop of limonite and manganese oxide marks the line of a lode-formation known as Balstrup's. The Zeehan public has always had a fancy for this huge outcrop, but the levels that have been driven under it have been too shallow to prove the lode below the oxidised zone. The porous nature of the country-rock has probably facilitated the formation of gossan, and this material, though of some use as a smelting flux, would seem to have been deprived of any ore which it may have originally contained. Whether it would repay any deep work depends upon what its original contents were. Some work on Balstrup's lode has shown the vein-type to be the sideritic galena one, but no information concerning values can be gained unless the lode is proved below groundwater level. The risk connected with such a venture is obvious, and is perhaps such as mining companies would not lightly assume, especially as experience (certainly somewhat limited) tends to show that lodes in the loose ferruginous strata of this series make a show at surface quite disproportionate to their size underground. Still the possibilities cannot be proved without deeper work.

Brennan's or Sheargold's Shaft.—This discovery is on the lease of the Mt. Zeehan (Tasmania) Silver-lead Mines Company, south of the Comstock railway, about ¼-mile west of the Summit cutting.

The find was made by Mr. Brennan in August last, and a shaft started upon it at once with the company's assistance. After a little work had been done operations were suspended. The lode-channel comprising a graphitic slate mixture from 2 to 4 feet wide, carries a metalliferous lode from 4 to 6 inches wide, mainly of a pyritic character, with galena, accompanied by a little antimony. North of the shaft the bearing is north-westerly; south of it the direction is north-south. The lode appears to traverse the country at the junction of black slate with greenish slate-tuffs.

Some assays of the ore made by Mr. T. Vincent, Jun., returned:—74 per cent. lead, 171 oz. silver; 49½ per cent. lead, 105 oz. silver; 38½ per cent. lead, 151 oz. silver; 70 per cent. lead, 125 oz. silver. For the depth sunk the lode did not improve in size. It has been exposed in a deep trench at a short distance north of the shaft, and also a couple of chains south. At the latter place it consists of solid pyrites, and the surface line is marked still further south by gossan and pyrite.

Tramway Lode.—South and west of the preceding, along the wood tram, a pyritic blende lode has been cut, and a small serpentine drive put in on it by some prospectors. Loose pyritiferous gossan in the end is only 10 feet below the surface. The zinc blende is argentiferous. The shallowness of the workings does not admit of much being said about the prospects of work here.

About 5 chains west of Brennan's shaft loose stones of decomposed granite porphyry, with phenocrysts of quartz and felspar, occur in a waterhole, about 100 feet south of the Comstock railway. The country-rock belongs to the slate-tuff series, and the occurrence is doubtless a dyke of Devonian granitoid rock traversing it.

Farther along the wood tramway is an open-cut in a gossan lode, from which some pyritous material has been obtained carrying a little galena.

In this part of the district we seem to be fairly in the area in which lodes of the pyrite-blende-galena vein-type prevail; but these ore occurrences have been placed in this part of the report owing to their situation within the boundaries of the consolidated lease.

Victoria-Zeehan Mine.

The Victoria-Zeehan Silver-lead Mining Company was registered in 1905 to work two 80-acre sections—1585-91M and 861-93M—formerly held by the Colonel North Company.

The western section is south of and adjoining the Spray block of the Mt. Zeehan (Tas.) S.L. Mines, Ltd., and is drained by MacLean's Creek and its small affluents. The hill rising to the north towards the Spray is covered with standing forest: the rest of the property is clothed principally with button-grass.

Grubb's tramway crosses the south-west portion of Section 1585, junctioning with the tramway from the Comstock about ½-mile further north, and forming a convenient means of communication with the railway-line at Zeehan.

One of the routes proposed for the present Comstock tramway was through the Victoria-Zeehan sections, and this would have had the advantage of serving the low-level mining properties between here and the Comstock, and of leading direct to the untouched timber belt which lies to the west. Some tunnelling, however, would have been necessary, and this probably influenced the rejection of the scheme.

The prevalent country-rock consists of white, grey, and yellow sandstone, quartzite, and dark slate. The slate associated with the lodes is dark in colour, often graphitic, and sometimes silicified. The strike of the strata ranges between N. 10° and N. 70° E., and they dip in a south-easterly direction. No fossil evidence of age is available, and grounds for referring the beds to the Ordovician, or Cambro-Ordovician, are perhaps not quite decisive. The Cambro-Ordovician tuff-slate series bounds these sandstones on the north and east, and the junction is evidently a faulted one, as the former has a different strike, viz., east and west, with a northerly dip.

Several silver-lead lode systems intersect the Victoria-Zeehan property in a general south-easterly direction. These are continuations of known lodes on the Mt. Zeehan (Tas.) S.L. Mines section on the north, and some of them evidently pass through the entire property, and across the Nubeena and South Nubeena sections further south.

The Spray lode system is perhaps the longest on the whole Zeehan field, being traceable for about 1½ mile at intervals through these sections. The Spray lode having yielded such handsome returns in the Mt. Zeehan Company's ground, the desire is natural to identify sections of lode on the same strike as being the same lode. This is hazardous, so long as they have not been actually connected, but there can hardly be any doubt that they belong to the same lode-system.

As far as can be seen at present, the lode in the Foam and Victoria-Zeehan workings and the pug lode of the old Silver Wave tribute further south are the continuation of the No. 1 Spray lode. Gurnie's lode in the Spray Mine (No. 3 lode) has been supposed to enter the Victoria-Zeehan property about 40 feet east of where the chloride lode is exposed, but the workings on each lode are very nearly in a line with one another, and it looks as if the two are identical.

Some uncertainty has been felt in correlating the Foam lode with the main Spray lode owing to the different dips in the two lodes. The Spray lode descends vertically, and then dips to the west, while the Foam lode dips north of east. This irregularity of dip, however, is in itself in no way surprising.

The Silver Foam Tributing Company, with a view of proving the continuation of the Spray lode, drove an adit for 600 feet in a north-easterly direction (40°), and intersected the lode at 400 feet. From the adit-mouth the country passed through is, first slate and clay, then sandstone, then slate again. A few small clay cross-courses cross the tunnel, but no quartz veins or signs of mineral. A drive north on the course of the lode did not disclose any ore, and a winze was then sunk on it to a depth of 100 feet. The present company opened out at 50 feet, and found a small vein 3 or 4 inches wide, carrying some nice antimonial lead ore. This was in the hanging-wall country. It was driven on about 25 feet south, and swells into a bunch 7 or 8 inches wide just behind the end. There is pug on the west wall with some ore in it. We are here just at water-level, and it is apparently at this horizon that the ore begins to make. The lode lies under black slate, and the other wall is pug and black puggy clay slate. A bulk sample of the lodestuff is published as yielding 20 per cent. lead and 19 oz. silver per ton.

The drive north from the adit is a channel filled with lumpy quartz and pieces of slate, about 5 or 6 feet wide, but not easy to define. Thirty feet behind the end the manager cleared out a hole in the level on the hanging-wall side to show a band of pyrite in pug and quartzose material 6 or 7 inches wide, and a small cuddy has been driven through it. Only traces of galena were found. The end of the drive is in soft, oxidised, clayey matter without any trace of lodestuff. Everything is oxidised, and the pyrite, which is an unaltered remnant of the vein, does not appear to have continued. It is very evident that any metal which was present at this level has been leached out.

The bearing of the lode here is N. 5° W., and its dip E. The country strata strike N. 60° E., and dip south-east.

The site for a main shaft has been selected so as to admit of cutting the No. 1 Spray lode by a crosscut east for 185 feet, and the Nos. 2, 3, and 4 lodes by a crosscut west for 300 feet. Sinking was started in 1907. When down 180 feet a burst of water took place, and a pumping engine had to be installed, which coped with the water easily, and the shaft was completed down to 310 feet in September, 1908. This is about 275 feet below the adit. A crosscut east was started, and driven to 215 feet. At 184 feet the lode-formation was cut, averaging 6 feet in width. A pug seam existed on each wall, and the intermediate portion was principally quartz, decomposed slate, and carbonate of iron gangue containing a little lead ore. The only place where some clean ore was met with was where the lode took a sharp bend; at this point it was broken and loose, and contained some broken pieces of galena. A drive north has been put in for 150 feet. At 45 feet from the crosscut a rise was put up for 30 feet, and some galena is reported as having been made in it in a small vein.

In March, 1909, the water increased too much for the power of the pumping plant, and underground work had to stop. After strengthening the plant an attempt was made to unwater the mine, but proved unsuccessful, and the idea of working at the 300-feet level with the present facilities has been now given up. The present intention is to open out at 200 feet, at which level it is believed that the mine can be worked.

The country passed through in the shaft was extremely soft, consisting of layer after layer of rotten slate, with thin beds of sandstone, and facing-boards had to be used in the crosscut until in the neighbourhood of the lode.

There is no good reason for doubting that the No. 1 Spray lode was struck in the Foam adit, and the lode driven on from the shaft crosscut must be the same. It is quite possible for the No. 1 lode to have changed its dip, and any difference of water-level between the Spray shaft and here need not be taken into account in considering the identity of the two lodes.

Silver Wave Workings.—These are on the eastern section of the company's property (861-93M), near the south-west corner. There is more than one lode here, but the vein-system certainly appears to be on the No. 1 Spray lode-line.

The line here strikes N. 30° W. and the lodes dip to the north-east. The accessible workings consist of a crosscut to the lode and an adit drive on the lode at about 40 feet above the crosscut. The bulk of the work was done 15 or 16 years ago, but more recent tributing work was relinquished about 12 months since. Two or three years' work produced ore of a gross value of about £500.

The adit has been driven in slate in a south-easterly direction. Veins of galena in the stope above the level have been followed, and stoped until they were worked out. The veins have the appearance of spurs running off from the pug lode, which lies east of and parallel with the lode seen in the adit. The fractures between the lodes seem to carry the ore.

A shaft at the entrance was sunk 16 or 17 years ago, apparently with the intention of picking up the pug lode. A little blende is visible in the mullock at surface.

From the general aspect of the lode-line, it might be doubted whether this lode has been cut in the crosscut from the main shaft, but with the great distance intervening any definite statement is hazardous. All that can be said is that it is on the same general line of the Spray lode system.

The crosscut below was driven a little south of east, and at 50 feet from the entrance a little galena was met with, facing the stone. This was followed for a short distance in a southerly direction, and a winze sunk on it to a depth of 20 feet. Further in the lode was intersected, and the crosscut continued to the pug lode, veins of ore occurring between the two lodes as above. Following the lode south the ground has been stoped out to the adit above.

The lode-formations in the Silver Wave workings do not appear at this level to be the best repositories of ore. The most ore fills the small fractures between the lodes, and there are no indications of any improvement taking place at this horizon. The best method of developing this ground will be by shaft-sinking.

Pyritic Formation.—On Section 1585-91M, south of the old Silver Beach shaft, and on the southern boundary of the section, a soft black pyritic formation has been trenched on up the slope of the button-grass covered hill parallel with the boundary-line. The subsoil carries crystalline pyrite, with a little cemented blende and galena and fragments of slate. Proceeding up the hill pieces of solid lode-matter are met with. An adit has been driven about 79 feet, but its maximum depth below surface is only 15 feet, and no lode was picked up. Pieces of resin blende and galena in banded form can be gathered at surface.

Still higher than this the pyritous subsoil appears to cease, and only dark slate and grey sandstone are present, A little stone has been cut here showing pyrite. A cut has been put in, showing the graphitic top of the lode-channel—4 or 5 feet wide. It is too shallow for adit work, but it would be well to sink and test this formation.

Tramway Formation.—On MacLean's Creek, east of Grubb's tramway, two holes have been sunk on a lode-capping of porous quartz and pyrites carrying a little galena and blende. The formation itself is 4 feet wide, and the ore-vein is about 18 inches. The zinc blende is the dominant ore, the galena only appearing in spots. The lode seems to be in graphitic slate, and, judging by the pieces on the mullock-heap, is strong enough; but the indications would be more encouraging if there were less blende. It has been trenched for both north and south, but so far has not been picked up again, and its direction consequently has not been ascertained. It is here in flat country, and probably enters the hill about 300 feet north of this spot.

The water from the creek may prove a little troublesome, but the lode seems well worth prospecting.

Silver Beach.—Only what is called the office adit is now accessible. The main shaft, situate in the northern part of Section 1585-91M, is the old Colonel North shaft, which was sunk to a depth of 200 feet on a large iron outcrop, solid at surface, but so soft a few feet down that it could be removed with shovel. The information about the workings is to the effect that from the bottom level a crosscut was driven north-east for about 450 feet, partly by the Colonel North Company, partly by the Silver Beach tributors, and partly by the Victoria-Zeehan Company. Two formations of siderite-quartz without galena were cut near the end of the crosscut. The one nearest the end has been tentatively connected with a lode exposed further north, but its identity can hardly be said to be established. According to the mine plan these formations dip north-east, while the other lode dips south-west. Still no other lodes have been intersected by the crosscut anywhere near where the ore in question should cross it. Further back in the crosscut a 4-ft. formation was passed through and driven on west. According to the surface-line, Gurnie's or No. 3 Spray lode is still ahead of the end of the cross-cut.

Nearly 200 feet to the south-east the office adit has been driven parallel with the crosscut in a north-east direction for about 600 feet, and at a level about 150 feet above the bottom of the shaft. The adit traverses a belt in which occur ironstone formations. At about a chain from the entrance the first ironstone is met with in a band about 6 feet in width. The country up to this is clay, and past it soft, decomposed slate. At 240 feet from the adit-mouth another iron formation, considered to be the main lode, is met with. This siliceous ironstone formation, which is more impure than the previous band, continues for about a chain, dipping east-north-east. Beyond it is banded slate, conformable with it and ferruginous. The country further in is gritty clay, and the end of the adit is in slate, slightly less ferruginous than the country passed through. The No. 3 Spray lode (Gurnie's) ought to cross the country somewhere near the end of this adit.

The adit is at too high a level to warrant much work being carried out from it, but the crosscut from the bottom of the shaft is in a position favourable for exploratory work. The shaft, however, is apparently in a condition which would require considerable outlay before any work could be undertaken.

Chloride Lode.—This is a lode in the northern part of Section 1585-91M, which has been worked on at intervals up to the northern boundary about 20 feet below the crown of the hill. It passes into the Mt. Zeehan (Tas.) Silver-lead Mines property, and at top of the hill has daylight workings, now fallen in. It seems to be a continuation of the No. 3 Spray lode, although that lode has been supposed to trend about 40 feet east of it.

A small adit has been driven for 30 feet by tributors, in light-coloured slate, and an upper adit was put in about seven or eight years ago on the lode for a distance of 100 or 110 feet. About 30 feet from the mouth is a winze from which the lode has been stoped in both directions. Ore has been won from stopes above the level as well as from underfoot. The lode carries bands and nodules of ironstone (hematite and mammillary limonite), the nodules containing silver chloride and native silver. At times some high-grade bunches were met with, going as high as 1000 oz. silver per ton; but in the principal stopes parcels are said to have averaged 40 oz. The face of this drive could not be seen, as the ground is soft and has run in.

Cross Chloride Lode.—This is seen about a hundred feet lower down the hill in a southerly direction. A shaft has been sunk about 50 feet on the underlay, and drives put in north-east for 30 feet and south for about 40 feet. Above the north drive the lode has been stoped out nearly to the surface, and a couple of stopes have been carried up at the south end.

The lode was picked up at a lower level, and an adit started. After driving about 100 feet the ground became hard, and work was stopped, leaving about 100 feet to connect.

The formation is about 2 feet wide, carrying veins of ore from 3 to 6 inches wide of a patchy nature. Some second-grade material is at grass outside the shaft. The latter was sunk five or six years ago by the Victoria-Zeehan Company, and the material mentioned was raised by tributors, with a view of ascertaining the nature of the lode.

The increase of water in the new main shaft has been unfortunate for this company, as the 300-feet level is one which commends itself as a very suitable one for exploration. At 200 feet it is considered the plant will be able to cope with the water. That will be a little over 100 feet below the general water-level.

The persistence of the Spray lode-system through the property should encourage exploration, and the aim should be to get below water-level, as there are everywhere signs of extensive leaching in the upper zone.

The outcrops of several lodes on the property show the existence of ore at various points, and expenditure on systematic prospecting seems to be warranted.

Very little work (only 150 feet of driving) has been done on the lodes below water-level, and consequently the value of the property has yet to be tested.

Nubeena Syndicate (*Section* 5115-93M, 79 *acres—A. J. Parker*).

This is situate east of the Colonel North property, and used to be called the Nubeena section. It is now being worked by the Venezia tribute, which has raised altogether 145 tons of ore.

In the northern part of the section there is a group of lodes observing a more or less parallel course in a north-westerly direction. These are Llewellyn's, Barnett's, Jaeger's, and Wylie's. They are virtually on the same line as the Spray lodes, Foam, and Silver Wave further north, and the position and general characters of Llewellin's lode harmonise with those of the main Spray lode.

which supports the contention that the lodes are identical. The continuation of this lode is seen in the south-east angle of the property, where it crosses into the South Nubeena section.

The old Nubeena lode is near the western boundary of the section, and its strike differs from that of the neighbouring lodes, being to the east of north. The present prospector is opening up a drive above some old workings on an ore-channel 4 or 5 feet wide, with a few inches of clean galena making in the joints of the slates. Some of the ore in the sole seems to be breaking away to the east. The result of assay of the clean galena is stated at 78 per cent. lead and 95 oz. silver. This agrees with the report of old assays returning 100 oz. silver per ton. The ore-deposit is of no size, but the quality of the ore is encouraging.

The main tunnel of the Venezia tribute is driven in an easterly direction, and intersects Jaeger's and Burnett's lode.

Jaeger's Lode.—This lode has been driven upon N. 10° E. for 60 feet, and south for 70 feet. A little ore has gone south, and was stoped. Seams of quartz, with pyrite and siderite, appear in the face of drive. In the north drive a little galena was won for a couple of stopes. The intersection in the tunnel was in the best place with 6 inches of nice ore. Seams were followed upward in a V-shape for 20 feet. The ground was loose, and flat seams run off east in cross-fractures in the lode-channel. In the end of the drive is black slate, with a little galena and banded quartz.

This end might well be continued: the lode-channel has been fairly wide all through, 4 or feet with splashes of ore continuously, and it seems worth further prospecting.

A comparison has been made between this lode and the Silver Wave lode on the section to the north, but the large pug formation is absent here.

No. 1 Lode.—At 180 feet from the tunnel mouth an ore-vein was passed through, and driven on for a few feet north and south. Northwards the wall shows a little galena in tight slate; southwards the country is blank with a crosshead in the end.

Barnett's Lode.—This is intersected in the main tunnel about 200 feet east of Jaeger's lode. Its general bearing is south-east. About 170 feet have been driven on the lode. The channel has an average width of 4 to 5 feet, with splashes of ore right through. The clean ore has a width of 1 inch up to half a foot, and generally keeps to the footwall side, with an occasional bunch in the centre. The lode is a pyritic galena one, and very little blende is present. Quartz and black slate accompany the ore, which on the whole is patchy. A pug seam follows the footwall all the way. The length of the ore-shoots stoped above the level for 100 feet in height aggregates 150 feet. The following assays furnished at the office of the syndicate indicate the average value of the ore sent away:—

1.	59·00	per cent.	lead,	38·00	oz. silver,	per ton.
2.	60·00	„	„	40·00	„ „	„
3.	61·50	„	„	42·85	„ „	„
4.	56·50	„	„	37·30	„ „	„

The drive north is being extended and a little ore obtained in driving. The lode-channel here is rather narrow. Locally this lode is considered to be a continuation of Gurnie's lode at the Spray.

Llewellin's Lode has not been cut in the main tunnel. The persistency of the lode-channels on this section makes it desirable to continue exploration at increased depth.

Sections 667-M, 77 *acres—G. E. Butler.*

This is known under the name of the South Nubeena section, and a lode which is considered to be on the southern continuation of the Spray line comes into the section from the Nubeena property north-west and adjoining. The exact connection of the different outcrops on this line is difficult to establish, owing to the intervals unworked between them.

Butler's Tunnel.—Work is proceeding in this beyond the lode already cut, with a view of intersecting a lode ahead of the present end. The lode cut has been driven on north-west and south-east. A good deal of stoping has been done north, but the air getting bad, work was relinquished, and crosscutting resumed. The south drive forks into two branches. The lode-filling consists of quartz, carbonate of iron, and slate of variable width—from 6 inches to 2 feet.

Section 741-87M—*J. J. Walshe.*

This section is that which was formerly held by the Central Balstrup Company, and has only recently passed into the hands of the present lessee.

A number of shallow shafts have been put down with a view to the testing of the known outcrops at a depth, but these attempts have invariably failed for want of machinery to pump out the water which was met with in every case.

The lode-matter to which most attention has been paid is of the sideritic-galena type. A system of lodes which appear to be all connected with one another runs through the central portion of the section. The strike of the several branches varies a little, but the whole system strikes a few degrees west of north. From this lode-system some bunches of clean galena have been obtained, which are said to have possessed a good assay value.

On the southern side of the Comstock tramway this lode traverses conglomerate, and there is an impregnation of the rock with siderite for some width. This belt of impregnated rock may in part account for the large amount of gossan visible on the line of this lode in the neighbourhood of the creek which runs along the Austral Valley.

On the southern side of the creek, near the southern boundary of the section, a shaft which was sunk 20 feet was just sufficiently deep to cut some very rich unoxidised ore. This ore is peculiar, in that it carries niccolite and ruby silver ores in addition to galena and some antimonial lead ore in a gangue of siderite. From this lode-matter returns of as much as 530 oz. of silver per ton and 30 per cent. of nickel are reported to have been obtained.

The country-rock at this place is the normal keratophyric tuff and slate. The abundant water met with prevented any work being done upon the lode, of which the strike cannot be said to have been ascertained. This lode is certainly well worth prospecting.

A number of shallow trenches and excavations have been made in the western part of the section at the foot of Manganese Hill, but in no case has sufficient depth been attained to give any conclusive proof of the value of the lodes. It appears to be improbable that such efforts as may be made without efficient pumping appliances will meet with success. The lodes which have been located on the property are worthy of serious trial, but hitherto they have been only touched at the very surface.

This description of the Central Balstrup has been furnished by Mr. L. K. Ward.

The Sunrise Mine.

The Sunrise Mine comprises two sections—1821-M, 71 acres, in the name of J. Coleman; and 2235-93M, 20 acres, in the name of G. E. Butler.

The lodes which have been worked are connected with the King-Bell line, of which they are the most southerly known portion.

The lodes were formerly worked from a shaft located in a sharp bend of the Little Henty River. From this shaft, at a depth of 50 feet, crosscuts were put out, and cut the Sunrise lode 45 feet to the westward, and the Bell lode 80 feet to the eastward. The two lodes converge at such an angle that they are expected to meet at a distance of about 200 feet north of the shaft. These workings have been flooded, and were inaccessible at the time of our visit. Two shoots of ore are stated to have been met with on the Sunrise lode, of which the first 50 feet in length carried an average width of 9 inches of galena. This shoot has been stoped to the surface. After a blank of 30 feet another shoot, 16 feet long, was found to the north of the first. This has not been stoped.

With a view to the deeper development of this vein another shaft was sunk to the west of the river, and 124 feet from the old shaft. At 107 feet a crosscut was put out eastwards, and cut the lode at 50 feet. At the point of intersection the vein proved to be 4 or 5 inches in width, and of excellent grade. Picked samples containing fahl-ore gave a return of 404 oz. of silver, 50·6 per cent. of lead, and 9·02 per cent. of copper.

A short drive of 13 feet was carried south. There is a break in the lode near the face, but metal makes again behind it.

A drive was carried northwards for 36 feet from the point where the crosscut intersected the lode, and a few inches of ore was found on the hanging-wall side of the lode. The strike of the lode, measured along this drive, is N. 15° W., and its dip 72° to the westward.

The stopes were carried up 18 feet above the back of the drive, and a little further north than the face of the drive.

From this part of the mine two parcels of ore, making in all about 8½ tons, were sold. The assay values of the ore of the two parcels were respectively 57·3 per cent. of

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This description of the Sunrise Mine has been contributed by Mr. L. K. Ward.

lead and 104 oz. of silver per ton, and 39 per cent. of lead and 106·7 oz. of silver per ton.

Work was suspended at this shaft until the water should be pumped out of the older workings. This work was in progress at the time of our visit, and was being carried on by means of a water-wheel worked by power from the Little Henty River.

The future operations of the company will be directed towards the exploitation of the Sunrise lode and the King-Bell lode proper, of which the former constitutes a branch. These branches are said to be a feature of the southern part of the King-Bell lode, narrow veins called "indicator veins" rich in fahl-ore being stated to junction with the main lode on its eastern side at different points along its course.

Kemp's Sections.

3105-M, 40 *acres*; 3037-M, 40 *acres* (*now Munro and Nicholas*); 3652-M, 5 *acres*; 3247-M, 12 *acres*—A. Kemp, mineral leases. Situate to the north of the King Extended Hill.

Section 3037-M.—A shaft was put down in the early days by Peter Irvine, and taken over afterwards by the Faheys. It went down to 25 or 30 feet, but on meeting with the lode the water was too strong to cope with. Outside the mouths of a couple of shafts is a little galena and resin-blende. The lode runs as a wide formation in black slate in a north-and-south direction.

The main workings are further north, in the centre of the sections. An underlay shaft has been sunk 16 feet; they could not get deeper owing to water. The lode was 2 feet wide, 18 inches of which were solid ore, but it did not last long—a quartz-blende galena lode. Nine tons which were sent away returned 70 per cent. lead and 25 oz. silver. The ore is galena and blende, associated with quartz. Thirty feet away a shaft has been sunk on a puggy formation, but was discontinued owing to heavy water.

Near here is a pan of limonite from 3 to 6 feet thick, which covers the flat valley floor for 4 or 5 acres.

Section 3105-M, 40 *acres*.—Further north a trench has been cut in the same crystalline blende lode as at the principal workings. A few small slugs of galena are visible in the loose, broken slate. Another formation of blende and galena has been struck further north, but a little to the west of this line. Tributors have sunk a little, and excavated the formation for 10 or 12 feet in width. The ore here is very fine-grained, while in the southern workings it is characteristically cubical.

The lode belt in these sections forms a zone of shattered slate. To prove it, deep working is requisite.

Section 3652-M, 5 *acres*.—A race about 20 chains long has been cut in a south-easterly direction through this section along the course of a quartz-carbonate of iron formation, in which some galena and blende have been found. The water of this race flows into Parting Creek. The heavy overburden in this valley conceals the outcrops of any lodes which may exist.

Kendrick's Show.—Up the valley to the north, on Section 3247-M, 12 acres, a formation has been struck showing resin blende in a brecciated and drusy quartz gangue. Some assays of galena are reported to have returned $\frac{1}{4}$-oz. silver per unit of lead. A couple of shafts have been sunk to a depth of about 30 feet on a north-and-south lode, and some orestuff was sent away.

The slate in this valley belongs to the upper zone of the Zeehan Silurians.

Section 3770-M, 56 *acres—H. D. Marsh.*

This is situate on the north-eastern slope of Mt. Zeehan, on the northern fall of the Oceana Hill.

There are two occurrences of mineral on the property: one known as Harris' Galena lode, the other as Marsh's Iron Blow.

The galena lode traverses white crystalline sandstone country about 300 feet above the Zeehan township. To the west, across the gully, is a ridge of conglomerate. About a foot of lodestuff is showing in an old open drive which has fallen in, and besides this there is gossanous matter. The veinstone is composed of quartz and carbonate of iron and pyrite, the latter intimately associated with the galena. The position is good for working by adit-level, as high backs exist above the outcrop.

Iron Blow.—This is south of the above, and is a carbonate of iron-limonite outcrop, with veins or bands of pyrite running through it, the whole half a chain wide, if not wider. Its apparent strike is N. 5° W., and it shows a large face of iron ore on the side of the hill about 30 feet in height. It cannot be far from the boundary of the conglomerate. It was taken up in the first instance with the view of supplying ironstone to the smelters, but has been idle apparently for want of capital. The indications are in favour of it being the outcrop of some metalliferous lode. Over 100 feet of backs are obtainable, and with the general revival of mining in the district some attempt to prove the deposit will probably be made.

Section 2906-M, 80 *acres—M. L. Woodhouse.*

Great Western Mine.—In the centre of the section a tunnel has been driven west intermittently for the past 10 years, across slate country for several hundred feet. For the last one and a half year driving has been suspended, but the owner considers that if work is resumed, and the adit driven to the western boundary of the section, it will thoroughly prove the value of the ground.

At 50 feet from the entrance drives have been put in 70 feet north and 30 feet south on a black slate formation, with veinlets of galena and pyrite with quartz. On the north wall of the adit at this point is a band of somewhat solid pyrite. A chain further in a similar formation has been driven on for a short distance north. Half a chain further the adit has passed through a graphitic formation with a little galena. At 25 feet behind the end a band of white clay a foot wide has been driven on 30 feet north and 20 feet south. This clay contains specks of galena. The face of the adit is in slate containing splashes of carbonate of iron, and there is a small quartz vein behind the end. Another 100 feet of driving is expected to reach a small lode which shows a brecciated outcrop on the hillside.

A good deal of work has been done here by Mr. Stevenson, with small results. The general idea of proving the country by the drive is legitimate, but the undertaking is a purely prospecting one.

(2)—The Pyritic Belt.

The Oonah Mine.

This mine has passed through many vicissitudes, being alternately worked by company and tributors, earning profits and dividends, and at one time heading the list of producing mines in Zeehan. It has, however, suffered from lack of developmental work, though a good deal of driving has been done on the galena lode course.

The present owners are exploiting the stannite ore-deposits of this mine, treating the ore in their smelting works at the south end of Zeehan. The property comprises 232 acres, adjoining the Montana lease on the east. The shaft has been sunk to 450 feet, and six levels opened out.

The main features of the mine are the two lodes known as the galena lode and the stannite lode. These are roughly parallel, coursing north and south, and dipping east. Both lodes in a northerly direction are deviated by a slide which strikes N. 75° W., and dips in an easterly direction. On approaching this slide the lodes bend round to about 30° west of north. The stannite lode emerges on its northern side further west; but the galena lode has not been seen. Both lodes will junction in depth, as though their dip is in the same direction, the former has a flatter underlay than the latter, and they dip towards each other. This junction is expected to occur at about 150 feet below No. 6 level.

The present work is on the stannite lode only, but the ultimate intention is to bore underground for the northern continuation of the galena lode. As the stannite lode is better in the bottom workings than at the higher levels, sinking on this will have to be proceeded with, and exploration for the galena lode will probably go on at the same time.

Formerly the galena lode was worked down to No. 5 level, a payable shoot of ore being followed down to that depth from above No. 1. Down to No. 4 this shoot lengthened, and in No. 5 a good length was stoped, but in the bottom level, which was started on a small vein near where the lode was expected to be met with, there is no indication of the main lode. There is a little pyrite in the end of the drive south, the latter part of which has been turned to a south-easterly direction. A few inches of pyrite, with splashes of galena, have been met with. If work is resumed here, the first task will be to pick up the lode, which may possibly be found west of the present end.

The stannite lode furnishes the mineral for which the mine is being worked. This is an argentiferous tin-copper-sulphide, which used to be handpicked to a product selling for 10 to 13 per cent. copper and 50 to 80 oz. silver per ton. The tin was not paid for, but eventually the buyers made a small allowance in certain cases. At present under the management of Messrs. Alexr. Hill and Stewart and Mr. Alabaster the lode is being developed, and two forms of product, viz., a copper-silver matte and a copper-tin alloy, obtained by a metallurgical treatment, the details of which are not available for public information. Mr. Stewart has kindly supplied us with an analysis of the ore, which will be found in another part of this report. The lode is a banded one, with well-defined bands of stannite, pyrite, and chalcopyrite. A fair quantity of quartz is present. Other minerals are bismuthinite, wolframite, and a little fluorite. In the adit workings workable quantities of galena occurred alongside the stannite, but this is not experienced below, and it is very rare to find galena in the stannite itself. In the north drive at No. 5, where the carbonate lode breaks through and junctions with the stannite lode, some galena occurs actually in the latter. We are informed that 17,000 to 18,000 tons of ore are calculated as being available.

Work is being carried on at Levels 4, 5, and 6. No. 3 level will not be used for future work, as the stopes from below will come up into this ground, which is rather poor. The lode has been lost in the southern drive at the latter level. Numerous small deflections of it take place in the level, and in the end a little crosscutting has been done without recovering it. At the commencement of this drive the slide carries a little stannite west of the intersection, and the mineral then swings round into the north stannite drive. This drive is on a poor lode: the present end is in slate, but there is no crosscut in the level, and possibly lode-matter may exist behind the apparent hanging-wall.

At No. 4 level the lode has greatly improved. In the south drive it widened to 6 feet, and formed a nice body of stannite. Above the level the stopes show 2½ feet of solid ore. This shoot extends for 120 feet. At some distance behind the end of the level the lode comes abruptly to an end, but ahead of this a strong mixed siderite and stannite lode comes in. The lode-channel is intensely graphitic. A little behind the end a little fahl-ore and stannite are seen. In the end the ore pinches. Good ore has been stoped from No. 5 level up to within 40 feet of this end. This is known at the mine as the West Carbonate lode. It is an important lode, but its real significance and relation to the main stannite lode cannot be understood until further work is done.

At Level 5 the stannite lode where intersected showed 2 feet 6 inches of ore. This block above the north drive has been stoped up between 50 and 60 feet for a length of 80 feet. On the west side of the drive the lode is interfered with by a 7-feet formation of carbonate of iron, copper, and iron pyrites, which enters its west wall. For about 25 feet the stannite continues as a thread along the level, and then swells suddenly to a width of 4 feet. After the break or blank the stannite makes into a much larger body of ore in the stopes above. In the end of the drive the lode carries dark stannite and iron pyrite, and with a contained horse of country is about 9 feet wide. In the south drive at this level about 20 feet past the crosscut, the ore at the end of a 160-feet shoot slowly tails out to an inch of stannite without any indication of faulting. The ore-shoot pitches southerly, and in the level below goes much further south.

At Level No. 6 a nice lode continues all along the north drive, but it is not quite so good as it is in No. 5, although the rise 20 feet up was better than in No. 5. It is joined by the carbonate of iron lode, as at No. 5 level. At the end of the drive the lode is behind on the west side. This has been penetrated, and found to consist of solid stannite for a width of 2 feet. The south drive from the crosscut carries a lode of pyrite, chalcopyrite. and stannite, the latter a few inches wide, but in the end the graphitic lode-filling is soft and running, pushing back the facing-boards.

From its influence on the lodes, the main slide is an important feature in this mine. It has evidently deviated, not faulted, the lodes, and has itself become a definite lode-channel. The main galena lode has joined it, and continued within its walls in a northerly direction, with traces of ore at intervals as far as the junction of the stannite lode with it. We are informed that in the early days bunches of ore over 2 feet wide were met with in it, and that there is still ore under the level. The deposition of galena stopped at the junction, or at any rate not more than a few feet further west, and no continuation of it has yet been found north of the slide. Future exploration will show whether the lode has terminated here, as is quite possible, or whether it reappears anywhere on the north side further west.

The stannite lode, on the other hand, on approaching the slide, bends round into it, and is prolonged north of it further west along its course. As it is not a faulted lode north of the slide it will be dependent for its channel to a great extent on the fissures in the country on that side. Consequently it may vary in nature and behaviour on each side, and the results obtained on the south side cannot be taken as an absolute guide to what may be found on the north side, though they do undoubtedly form the very strongest justification for perseverance in the energetic policy which this company has initiated.

The mixed stannite and siderite lode in the end of the south drive at No. 4 bears S.W.-N.E. The north-east bearing would be the line of what is called the North Carbonate lode, which is in No. 4 level. This lode crosses the slide at the junction of the main galena lode with the slide, and carries a little fine-grained galena and fahl-ore, associated with quartz, siderite, and pyrite. The ore is a narrow vein and bunchy. The silver values are connected with the antimonial ore.

An unexpected discovery on the Oonah property has been that of a small lode of cassiterite in the hill east of the gully near the mine. It runs west into the hill, and dips north. Black slate encases the lode, but the country-rock of the hill is white sandstone. It has been exposed for a few inches in width, but has been uncovered so little that it is hardly possible to say accurately how wide it is. The ore is a grey oxide, resembling the tin ore of North Dundas. It carries pyrite, which is also represented by numerous cubical cavities. The lode is perhaps, too small to be workable, but it is interesting as being a unique occurrence of tin oxide on the Zeehan field, and as a further illustration of the connection of the Oonah lodes with the stanniferous granitic magma. In this connection it may be mentioned that we are informed by Mr. Stewart that the solid pyrite which occurs in the Oonah Mine, as well as in Bruce's ore, contains by assay 0·3 to 0·4 per cent. Sn.

Bruce's Tribute on Oonah Section 1110-87M: *Bradshaw's Lode.*—The pyrite deposit on this section is being exploited for the supply of material for the manufacture of sulphuric acid.

The lode appears to consist of a series of overlapping lenses of pyrite, some of which have a width of 30 feet and upwards. Its general strike is north-east, and dip to the south-east. Adits have been driven at three levels, the lowest being Brice's tunnel; Bradshaw's tunnel is 60 feet higher than Brice's, and Walshe's tunnel 60 feet above Bradshaw's. Leatherbarrow's tunnel is at about the same level as Walshe's. The two latter are on the course of the lode; the others are adit crosscuts. Above Walshe's is an open-cut, and at the top of the hill a shaft has been sunk on the outcrop.

Brice's tunnel is an adit driven west for 700 feet across slate and spilite tuff. At 100 feet in, the tunnel passed through a galena vein, and at 90 feet further a formation was crossed, which has been tested by a short drive north. At 280 feet from the entrance the country changed from tuff into hard slate, and at 50 feet behind the end the lode-formation was met with, and has not been cut through yet. Five stopes wide were taken out, and three high, when there was a fall of ground owing to lack of material for filling.

Bradshaw's tunnel passes through vesicular spilite to within a few feet of the lode, when the igneous rock passes under slate. The lode appears to consist of replacement seams of pyrites in the country; the associated quartz is somewhat vughy. The lodestuff is being taken out for a width of 25 feet.

The whole of the output has to pass through the mill, as there are numerous bands of country-rock in the pyritic formation; even in the solid pyrite a certain amount of clay is always an associate. Despite the obvious diffculties of mining and concentrating, over 100 tons of pyrites a week are sent away from this mine.

The ore carries a little copper (not more than 1 per cent. in the concentrates) and 0·3 to 0·4 per cent. tin. Apart from the pyrite, chalcopyrite is likely to be the economic ore met with in future work.

Pastkuchen's Lode on Oonah Section 1111-87M, 77 *acres.*—This is situated on the eastern fall of the Oonah Hill, above the mine, behind Bruce's tribute. The lode strikes N. 40° E., and has been worked in a shaft and trench. The bulk of the veinstuff is coarsely crystalline pyrite, with bright galena and strings or bands of zinc blende. The lode traverses slate which strikes N. 60° W., and dips south-west, and it contains a certain amount of undigested slate impregnated with quartz. An interesting feature is the presence of tin in the pyrite, which has been assayed in the Oonah laboratory, and found to contain 0·3 per cent. tin.

Junction Lode on Oonah Section 819-87M, 80 *acres.*

The shaft on this lode is situate near the north-east boundary of the Oonah property, and the Junction Company exploited the lode as it left the western section, where it was profitably worked. Four levels have been opened out, but the mine has been flooded since the Western closed. There is said to be a strong poor lode, principally of carbonate of iron, in the lower workings. As we could not see this mine, we were unable to form an opinion of the lode.

Clarke's Lode on Zeehan-Queen Lease 3918-M, 258 *acres.*

This lode traverses the country on the northern fall of the hill which bounds the Queen Valley on the south, and has a general bearing of N. 30° E., dipping south-easterly into the hill. It has been worked for galena from the Queen shaft, but much of the ore carried argentiferous stannite. The only means of access at present is the crosscut adit from the road, which has been driven to the lode a distance of 50 or 60 feet. The lode has also been reached in the 110-feet and 210-feet levels from the Queen (Nos. 1 and 2 levels).

Where the adit intersects the lode the country on the footwall consists of spilite tuffs, and that on the hanging-wall is slate. The lode follows the junction of these. In the south stope above the level the lode-channel is 4½ feet wide, with a horse of country. The solid ore-bearing part is 2 feet wide. On the footwall is a band of 6 inches steel-grained galena, outside the apparent wall; otherwise in the lode itself there is not much galena. The shoot here is about 30 or 40 feet long. It has been stoped for galena further north, however, for a hundred feet. The whole shoot is nearly 200 feet in length, with intervals of lode-stuff carrying stannite. Only the galena used to be taken out, and the rest served as filling.

The crosscut has been carried beyond the intersection. A small band of argentiferous galena was passed through, and further on a parallel lode of blende, galena and pyrite was struck, and a few tons of galena were broken, valued at 30 per cent. lead and 30 oz. silver per ton. The ore, however, feathered out, and only a few stringers are left.

Clarke's lode is a composite one of banded galena and stannite, with a little chalcopyrite, in which the stannite has hitherto been neglected, no allowance being made for it in purchasing. The silver yield of the ore sold used to be about 70 oz. per ton. A picked sample of the stannite ore from the lode, assayed in the Oonah Mine laboratory, contained 8·5 per cent. tin, 6 per cent. lead, and 57 oz. silver per ton, 8·9 per cent. copper and 7 per cent. silica. Mr. T. Vincent, Jun., former manager of the Silver Queen property, furnished us with assay contents of 20 tons of stannite ore from this lode, viz.:—Copper, 16 per cent.; tin, 14 per cent.; silver, 78 oz. per ton.

Cornish and Prairie's Tribute on Zeehan-Queen Lease 3918-M.

These workings are on the Zeehan-Queen property, on the south side of the valley, above the road leading to Trial Harbour.

An underlay winze or shaft is being sunk on the western continuation of Clarke's lode, which has here a quartzo-pyritic gangue, carrying clean galena with a speck or two of antimonial ore. The lode strikes N. 30° E., and dips to the south-east at about 55°. It passes across black and greenish slate. No. 1 level of the Queen Mine passes 150 feet below the bottom of these workings.

E. S. Clarke and Party on Zeehan-Queen Lease 3918-M.

These workings are further up the Queen Valley, on the same side as the preceding.

The outcrop of a galena lode at surface bears N. 41° E. in slate country, and dips south-east. Clarke's lode appears to be east of this line.

An upper crosscut tunnel has been driven about 60 feet across slate, and the lode driven upon north and south. The drive north shows a porous lode-channel about 3 feet in width, carrying a little galena all through. A seam appears to be descending underfoot on the hanging-wall side. The south drive shows a well-defined footwall for about 25 feet, but the lode grows poorer in this direction, and there is no galena in the end.

About 80 or 90 feet below this is a lower crosscut adit, which is being driven into the hill in a south-easterly direction. The rock at the entrance is brecciated spilite tuff, which passes below black slate at about 1½ chain in from the entrance. At about 150 feet from the mouth a soft formation of black puggy pyritous material 3 feet wide has been passed through. A formation has also been cut just behind the end carrying a few splashes of galena and carbonate of iron. The adit has passed through hard beds of quartzite alternating with softer country, and the face is in dense quartzite. The lode is supposed to be a few feet further ahead.

Montana No. 2 *Mine* (*Section* 1636-M, 58 *acres*).

Work has been carried on here by the Zeehan-Montana Company in five levels from the old No. 1 shaft of the Silver Queen Mine, placed close to the south boundary of the section. The greatest depth attained is 500 feet from surface.

Two galena lodes have been intersected and driven upon, viz., No. 1 striking north-easterly, and No. 2, a little further west, striking north and south. A long exploratory crosscut has been driven for over 1400 feet towards the Despatch Flat from No. 2 level, intersecting, however, nothing of importance.

From 1902 to 1909 this mine has produced 27,000 tons of ore, of which only a small proportion was first-class. The silver ratio is much lower than in the ore of the Montana No. 1, the two being 0·6 oz. and 1·2 oz. respectively to the unit of lead.

We inspected Nos. 2, 3, 4, and 5 levels. The first lode cut west of the shaft is No. 1 lode.

No. 1 *Lode.*—As seen at No. 3 level, it is nearly vertical or slightly heading west. Here where cut it is only from 1 to 5 inches wide, and not payable. In the end of the leading stope over the north drive it is reduced to a mere track in graphite slate. From here back the lode is blank for nearly 100 feet, and then there are 50 feet of profitable ore to be worked out beyond on this level. In the south drive the lode is faulted: only a track discernible, with a few specks of galena.

At No. 4 level in the north drive the width of the lode averages 6 inches, and finally it disappears. The lode dip from here down to No. 5 is easterly, but upwards it is westerly. The end is blank, showing merely a band or two of quartz and carbonate of iron. In the south drive the lode is cut off by a fault at the boundary of the section.

At No. 5 level in the end of the north drive only a small lode-track is apparent, in black slate, and not carrying any galena. Above this the lode was 6 inches to 1½ feet wide. The greatest width attained was 3 feet. It has really been a small lode all through, but the silver ratio was much higher than that of No. 2 lode. In the south drive, 15 feet behind the end, a bar of hard rock cuts the lode off, and the drive passes into a loose channel or fault-fissure filled with broken stuff mixed with carbonates. The lode seems to have deviated sharply to the west, and at the point of deviation there is a marked graphitisation of the slate, which extends south for a few feet on the line of the original lode-channel.

No. 2 Lode.—This produced a good deal of ore from the upper levels in former years, and was examined by us as far down as No. 4 level. It has since been cut at No. 5. Above No. 3 it has been stoped for a length of nearly 500 feet. In No. 4 north drive it dwindles to a track with occasional quartz and pyrite. Over the south drive metal was being stoped in patches. At the end of drive it disappears at a slide.

This lode as a whole is a complex formation, marked by a divisional plane and some broken country on its east wall. The ore is found in irregular bunches or lenses in this broken country. Followed north it degenerates into unpayable stringers. Southwards it has been traced into the Queen ground, and there worked on royalty.

Certain main features are noticeable, viz.:—

(1) The lenses or makes of ore are disposed in the slate very irregularly.

(2) These lenses terminate completely when followed north, but the lode-channel continues as a seam of pug.

(3) The lode-channel is a fault-line, as is proved by the dislocation of a markedly white band in the slate.

(4) A slide of pug breaks the lode going south, which reappears to the south-east on the other side of the fault. The lode, however, has probably not been dislocated, for no broken ore occurs in the slide.

(5) There are a number of minor flat faults on the south-west side of the slide heaving the ore a few feet at a time.

(6) The tendency throughout is for the pyritic type of vein to be represented.

At each level the lode has been driven on north and south, but the long drives are the north ones.

At No. 2 level the south drive goes to the section boundary, showing in the end a little galena and pyrite. Over a foot of mixed low-grade ore continues into the next section. In the parallel south drive, which is a footwall one, the end is pyritic with a little galena. Thirty feet above this the hanging-wall and footwall approach to within 6 feet. Here they are 20 feet apart, and from here down seem to behave as two lodes.

In the north drive the length of the stopes is about 100 yards.

At No. 3 level the lode in the south drive degenerates into pyrite, with traces of galena. A band of pyrite sometimes 3 to 4 feet wide follows the east wall; this can be seen on three levels. A thin vein of galena is encased in pyrite. The stopes above the north drive on lode have a length of about 350 feet.

At No. 4 level the lode over the south drive is patchy, and the ore splits as it goes north. To the south the ore makes under a slide, and is picked up again 50 feet in to the west. This is now being driven back upon. Beyond are other slides which have heaved the lode 9 feet a few times. The ore disappeared in driving north. The wall has been followed a few hundred feet showing a lode-track with occasional quartz and pyrite, but no ore.

At No. 5 level the crosscut for No. 2 lode was being driven at the time of our visit. Its north-west continuation was in a wide band of pyrite following the strike of the country, but separated from the slate by a soft dig. This band was kept on the north side of the crosscut, and the latter turned west, crossing only small formations of pyrite 6 inches and 1 foot wide.

Between Nos. 1 and 2 lodes in this mine is a mass of mixed silica, pyrite, and siderite, in which pyrite strongly predominates. This is only partially exposed, and its precise form is not known.

No. 1 lode hardly exceeds half a foot in width on an average, but carries ore of better grade than No. 2. Some of it has returned 1 oz. silver : 1 unit of lead. It has, however, been nearly all stoped out above No. 4 level.

Working results cannot be described as satisfactory. The increase of pyrite and the absence of ore in the lower workings are discouraging; still the presence of pyrite itself is intrinsically no reason why galena may not reappear in a lower shoot.

Barnett's Lode.

This is a galena lode on Section 3835, 52 acres, about 1½ mile west of the Western Mine.

The history of work is somewhat singular. A little galena was found when washing the creek gravel for gold many years ago, and a start made to drive on a small vein. The late proprietor resumed work on the lode, and though he did not win more than £120 worth of ore in driving 60 feet, the outlook was promising enough. After his death, the Zeehan-Montana Company took up the work, but with disappointing results. The ore in the main drive disappeared the first day, but 20 feet further in the shoot made again for 4 feet in length only. A rise put up showed that the ore did not ascend, and a winze disclosed that it did not go down. A stope over the level proved the shoot not to go up more than 2 feet. The form of the shoot appears to be that of a lens 10 feet wide in the thickest diameter, and not more than 30 feet in length altogether. South of this the lode in the drive closes up, and only a track shows. In the end it is quite broken up, and carries merely a little pyrite. For the last 60 feet both sides have been carried, and care has been taken to be sure that nothing has gone off on either side. The general direction of the drive is S. 20° W. The country-rock is a light sandstone, striking west or a little north of west, and dipping in a northerly direction. The lode has been found on surface 700 feet further south.

A dyke of granite porphyry crosses the entrance of the drive, bearing N. 18° W., and the lode is faulted at this point.

In the level below the rise to the open cut a shaft has been sunk 37 feet, and at this depth the lode consisted of solid pyrite.

The lode is a quartz pyritic one, with very little blende associated with the galena. In the north end, where the galena ceases, it is replaced by zinc blende; otherwise it gives place to pyrite. Where brecciated the lode has a filling of quartz and siderite.

The ore won was worked up to 60 per cent. lead and 45 oz. silver per ton. It had to be packed a mile to the Western tramway, and then trammed 2 miles to the Montana Mine.

There is still a little ore along the level, but apparently not worth taking out. The optionee (the Zeehan-Montana Company) will now have to consider the advisability of continuing or relinquishing work at this mine. There is certainly nothing particularly encouraging in the proposition as opened up at present. Those who have been working it take the practical point of view, and look upon it as simply an isolated patch of ore. This is a very natural conclusion, and yet one may question whether it is a correct one. The patch was a very solid one while it lasted, and nothing in nature warrants us in believing that such patches ever do occur absolutely isolated. It would be more reasonable to assume that they are disconnected parts of an ore occurrence. To prove this, however, would involve outlay and risk of some amount of capital.

A. D. Sligo—3797-M, 40 *acres.*

This section is north-east and adjoining Barnett's section, and the lode apparently passes into it and through it, changing its course from north-east to northerly. No absolute connection has been proved, and there is a considerable distance between the works on Barnett's ground and those on this section, in which the outcrop is not visible. The nearest opening is Kerslake's shaft, a chain from the southern boundary. This has been sunk on the lode to a depth of 15 feet—in the early part of last year. The lode is here vertical, with a slight westerly underlay. It is a pyrite-galena lode, the gangue being mostly pyrite with a little quartz. The galena is coarsely cubical and clean.

About 50 feet further north the lode has been cut down into, showing quartz and pyrite. The lode-line at surface is marked by signs of silicification. The encasing country-rock is black graphitic slate.

Quigley's Workings.—These are further north, where the track from Zeehan crosses the lode. An open drive south has been put in for a chain from the track. A pass from this drive connects with a lower tunnel. Some stoping has been done, and a little ore was sent from here. The lode-channel is about 3 feet in width, with a smooth, nearly vertical, hanging-wall. The ore is extremely pyritic.

The low tunnel is about 50 feet lower down the hill, and has been driven south-east for about a chain across black slate before cutting the lode. A drive north for about 40 feet followed a well-defined lode-channel. No galena visible. The pass from surface comes down into this drive. The north drive is about 30 feet long. A wide end in lode slate, but poor. The lode seems to split and send off spurs.

Outside the tunnel a small pile of galena is stacked. The type of vein is intermediate—pyrito-sideritic. A little chalcopyrite is visible in the ore, and a very little blende. The parcel sent to the Smelters last year assayed 62 per cent. lead and 42 oz. silver.

It is stated that where the crosscut struck the lode there was pretty good ore on the hanging-wall, 9 to 10 inches wide. A rise came into ore at 20 feet up, and showed the shoot pitching north. Four stopes were taken out, and the shoot lengthened from 4 to 25 feet. There were veins of galena all through a wide formation. North of the rise there is still said to be ore unstoped, but it is thought that owing to the pitch of the shoot ore will be found further north. The lode has been trenched again on the section further north, and still further outside the north boundary a trench has been put in up the hill east.

Wells' Tunnel.—On Crown land, north of Section 3797-M, a low tunnel has been driven south of east, across glacial till or mudstone conglomerate and slate, with a view of intersecting some galena vein supposed to have been found at surface. In the end of the tunnel are some small veins of quartz and iron carbonate, and some way back from it a small vein was passed through. Nothing has been seen beyond a little pyrite. The tunnel has been driven 120 feet. Some trenching further north has also not disclosed anything very definite.

Susannite Mine (*Section* 1929-M, 62 *acres—A. J. Omant*).

This is situated south of the Comstock Railway, east of R. Quiggin's section—2073-91M.

There are two parallel lodes, 3 or 4 chains apart, running west of north. The westerly one, though 16 to 18 feet in width, is of the less importance in respect of silver contents. The easterly one is explored by a crosscut adit driven N. 25° E. through slate, and then nearly due east across wide lode-formations: first through kaolinised rock with disseminated pyrites, then through a broad band of loose pyrite, and finally 12 feet into lead sulphate bearing gossan, which is still very solid in the face. The formation is stated to contain silver occasionally reaching a fair percentage. Some sulphate of lead and mimetite (or campylite) is present. The latter was formerly conjectured to be susannite, a variety of leadhillite (sulphato-carbonate of lead), hence the name under which the mine is known. There is a little carbonate of lead in the pyrite. The secondary ore has given high returns of silver, and some of the pyrites, we are informed, returned over 1 oz. of silver per unit of lead.

By sinking it is probable that an enriched zone would be reached. The possible backs over the present tunnel cannot exceed 50 or 60 feet, and altogether sinking is the only feasible way of opening out and proving the lode. The outcrop is large, and consists of limonite.

Further north, nearer the railway-line, is a high outcrop of limonite, and a short adit has been driven south, intersecting the lode below this. The veinstuff is quartz and disseminated pyrite. A few specks of blende are visible.

These dense pyritic lodes may be expected to carry shoots of galena, but these will require locating.

Colonel North Mines and Railway Company, No Liability.

Sections 1674-87M, 60 acres; 1562-87M, 80 acres; and 3465-M, 80 acres.

This is the old Grubb's Mine on Section 1562-87M, and was worked by Grubb's Silver Mining Company in the nineties. Work appears to have been commenced by driving two adits, one on each side of MacLean's Creek, the southern adit being on the course of the lode, the northern one a crosscut. The old company put £15,000 into the construction of a tramway a distance of 3 miles, connecting the mine with Zeehan, and started a main shaft which has been sunk to a depth of 320 feet, with crosscuts and level drives opened out at 130 feet, 200 feet, 270 feet, and 320 feet. Above the 130-feet level is an intermediate one, and 30 feet below surface is the adit.

The initial operations of the company were highly remunerative. The lode in the upper levels ranged from 1 to 3 feet in width, and the ore won was of a quality yielding nearly 1 oz. silver per unit of lead. The mineral now being raised comes mostly from above No. 1 level (130 feet), and the marketable product is worth 60 per cent. lead and 40 oz. silver per ton. The lode where it is now being worked is about 2 feet wide, and patchy. Some stopes are also being operated above Nos. 2 and 3 levels.

No. 1 Level.—For the first 70 feet of the drive north at this level the lode averaged 3 feet in width, 40 per cent. of which was reported as high-grade galena. The following 50 feet passed through second-class ore averaging 15 inches in width. The lode then turned to low-grade ore of varying width. It may be noted that a concentrating plant had not then been installed, and the galena in the second-class stuff was so intimately mixed with zinc blende and carbonate of iron that it could not be hand-dressed profitably. The carbonated lode-channel has been followed north, but the ore has pinched. In the end the lode has split into thin bands of pyrite, siderite, and a quartz stringer or two. Behind the end is a small puggy sideritic crosscourse, which has been followed east. After continuing the crosscut 40 feet a short drive north has been put in on a lode-channel said to have contained a little ore.

At about 70 feet north of the main crosscut a southwest crosscut has been put in. This passes below the Maclean Creek, and the country traversed all through is somewhat loose and broken. At about 200 feet from the main drive the crosscut passed through a formation, and at about 90 feet further west the Grubb's west lode was intersected and driven on north and south for about 30 feet each way. The appearance underground is that of the intersection of two veins, one bearing a few degrees west of north and the other N. 40° W. The first has shown some clean galena, assaying 73 per cent. lead and 75 oz. silver. The crosscut will be kept going with the view of cutting a formation met with in the south-western tunnel workings. The continuation of this formation ought to be met with within about 170 feet from the lode recently cut in the crosscut.

The south main drive at the 130-feet level is on an irregular lode. This is being worked above the level. Its width is 2 feet, in places 5 or 6 feet. The level shows a graphitic slate lode-channel in a belt of altered country. About 40 feet behind the end a winze has been sunk 15 or 20 feet on some irregular veins of ore. In the end of the drive a lode-channel is exposed for 3 feet in width, with two well-defined walls, each wall carrying a little ore (galena and blende)—about a foot wide on the hanging-wall and a thin skin of galena on the footwall. Some green micaceous mineral is associated with the carbonated lode-stuff. This end is over 300 feet from the main crosscut. No continuous shoot of metal is observable, but the pay-shoot occurs rather as a succession of separate lenses.

No. 2 Level (200 *feet*).—From a short crosscut west levels have been driven 200 feet north-west and 240 feet south-east. The lode-formation is 6 to 8 feet wide in the north level, with a vein of 5 inches of blende and galena on the hanging-wall (west), and 2 or 3 inches on the footwall (east). A crosscut west has been driven in lode-matter. All has been stoped above this level and down to No. 3. Between here and No. 1 were some nice makes of ore, but a good deal of zinc blende was present. Over the level the lode has been stoped for a width of 2 feet. In the end of the south drive it is now 10 inches wide, and is a brecciated mixture of blende and carbonate of iron.

No. 3 Level (270 *feet*).—From a short crosscut west a level has been driven north-west for 235 feet, and a level south-east for 330 feet. In the north drive the face in the end shows a wide lode-channel, 5 feet wide, with only the track of a formation, without galena or blende. In the level a little galena is still showing. A winze has been sunk on a blende formation 7 feet wide. In the drive south a bulge of ore was worked in the sole some distance in for some 15 feet in width. Blende predominates in these lower levels, and the drive south may be said to be on a blende lode. A bunch of blende makes just at the slide behind the end. This slide does not appear to have faulted the lode, which continues on its course to the end. As far as can be seen, through the water pouring from the roof, the lode in the end is barren. The stopes between Nos. 3 and 2 levels have been in a lode-channel 5 feet in width, with about a foot of ore.

No. 4 Level (324 *feet*).—From a crosscut west levels have been driven north and south. The north drive is on a lode-track without ore. In the face is altered, carbonated country, with a narrow band of pug on the hanging-wall. Some doubt has been expressed as to whether this drive has actually followed the main lode, but there seems to be no good reason for questioning this. A short crosscut west passes through altered country, and then through a vein of zinc blende, which has been driven a little on in a northerly direction. The south level is blocked beyond a point below the end of stopes in No. 3. Ahead of this fairly good ore was followed down from No. 3 to within 10 feet above the back of the bottom level. A crosscut east from the shaft has been driven to cut a barytic quartz formation which was passed through in sinking. This is a hard-banded formation of some width, lying rather flat.

Gossan Workings.—These are shallow workings on the west side of the creek. A drive has been put in in a westerly direction across and partly on the course of a belt of silicified and oxidised country striking north-west dipping north-east, and containing some green-stained veins having the general bearing of Grubb's lode. Some crystals of magnetite are disseminated in this stained rock. The south-western crosscut from No. 1 level is intended to strike this formation further north and test its value. At present nothing definite can be said about the prospects.

North-Western Outcrop.—On the spur north-west of the mine are a couple of short drives, and a winze sunk on a lode-outcrop stated to be Grubb's lode. Some galena is showing on the tip. This is about 400 feet west of the tramway, and 100 feet above the creek. Why work was suspended here is not known. There are fair backs to go under, and altogether the occurrence deserves prospecting.

Railway Cutting.—The tram-line near the mine passes through a formation about 100 feet wide, consisting of twisted and graphitic slate with a good deal of brecciated stone, silica, and pyrite. A few specks of zinc blende are disseminated in the quartz.

Adit Crosscut.—This is about 250 feet north-west of the main shaft, and has been driven west for 150 feet. Near the entrance it intersected the east lode, which here shows a channel of carbonated pug which is said to have carried a few streaks of galena. A drive north from this crosscut had occasional bunches of ore. The lode is crossed by a fault or course, which also cuts the lode below No. 1 level, and no ore of any consequence is found north of it.

Machinery.—This comprises a Tangye 20-inch cylinder pumping-engine; a pair of 10-inch winding-engines, Gates' crusher, 16-inch rolls, Wilfley concentrating-table; Woodbury table; and four sets of three-compartment jigs. The proportion of firsts to seconds is about 1 : 4.

Remarks on the Ore Occurrence.—The lode has a north-westerly bearing, and dips easterly down to the 130-feet level, but at about 160 feet between Nos. 1 and 2 levels the dip changes to a westerly direction. The lode-channel has an average width of 2 feet, and when it carries ore the latter has a width of from 8 to 10 inches or thereabouts. The lode is a blende-galena lode with a sideropyritic gangue. The stoping length of the deposit is about 360 feet, but the ore is not continuous throughout its length.

The ore is said to be poorer in silver in proportion to the increase of blende and pyrite, and the best values are recorded from within 200 feet of the surface. A split seems to have occurred at No. 3 level, a portion of the hanging-wall going off westward. The lode in the bottom level is very zincy, and a winze from the sole went down 15 feet in zinc blende; but this feature is not necessarily a function of depth, for between the adit-level and surface the lode is said to consist largely of blende and pyrite. At the same time the prevalence of blende in the lowest level is disappointing, and the appearance of the lode in general at that level is, on the whole, not very promising. On the other hand, there is nothing to show that the bottom of the galena zone has been reached. As long as the blende continues, there is the chance of galena shoots reappearing, either on the horizontal extension of the lode or at a still lower horizon. If better results do not ensue from explorations above the lowest level a final course must be taken of sinking the main shaft a few hundred feet deeper, to try the ground below the shoots worked in the upper parts of the mine.

Swansea Mine (633-M, 10 *acres—L. Murphy*).

This is a section situate to the north of MacLean's Creek, west of the southern section of the Colonel North property, and is being worked by a Zeehan syndicate.

The lode consists of galena and resin blende. An adit has been driven S. 50° E. for 200 feet on a flat lode dipping north-easterly, and east of this a small shaft has been sunk 60 feet, from which a drive is proceeding to intersect the lode below the tunnel.

The lead is remarkably clean, but the silver content is low, being about ½-oz. silver per unit of lead.

The outlet for this mine is *viâ* the Colonel North tramway. It is distant from that mine by track about half a mile.

Section 1244-M, 40 *acres, and* 3106-M, 40 *acres—C. Brumby and A. Nicholas.*

These comprise the old T.L.E. and Stonehenge sections. Section 1244 is the one through which the two T.L.E. lodes pass with a N.E.-S.W. strike. The main shaft was sunk to 100 feet, and levels opened out on the lodes, which yielded a high-grade blende-galena ore, reckoned as the best in the Comstock district. Work has been carried on intermittently by tribute in recent years, but we are informed that in this period 250½ tons of ore have been raised, realising £3769. The following assays have been furnished to us:—76·5 per cent. lead, 105 oz. silver; 75·5 per cent. lead, 105·3 oz. silver; 75·4 per cent. lead, and 111·8 oz. silver—per ton. Only on one lot was there a zinc penalty. On the occasion of our visit the shaft was being unwatered.

The Stonehenge Mine is situate to the south-east of the T.L.E. Mine, and south of the old Tasmanian tramway. The ground is low and flat, and mining work has been greatly interfered with by water.

There is more than one lode on the property, but only one is being worked. This is a parallel one to the T.L.E. lodes. A shaft has been sunk on it to a depth of 60 feet, and two levels have been opened out, at 30 feet and 60 feet respectively. The strike of the lode is N. 20° E., and it is nearly vertical, the dip in the upper workings being slightly south-easterly and changing below to north-westerly.

The ore contains a little copper and iron pyrites and a great deal of zinc blende, among which the galena appears in bands and blebs. What non-metallic gangue is present is chiefly silica, with siderite in occasional splashes. The metallic minerals fill almost the whole of the lode-fissure, adhering tightly to the walls, but not passing beyond the fissure in such a way as to produce an impregnation of the country-rock.

The upper level (at 30 feet down) has been driven north and south for nearly 200 feet on a bunchy formation about 18 inches in width. The shoot of ore north of the shaft is narrow—from 5 to 6 inches in width—but is readily followed, since the track of the lode is plainly visible even when the metallic minerals disappear. At 35 feet north of the shaft a fault was met with striking N. 80° E., and dipping very steeply towards the north. By this fault the northern portion of the lode is displaced 4 or 5 feet to the east. Some stoping has been done above the level as far as the slide, and for a few feet north of it. Up to the slide the stopes go nearly to the surface; north of it only one stope has been taken out. Some ore is still visible in the back, and some good ore is visible under foot at the end. On the same level on the southern side of the shaft a drive was continued till a connection was made with an old shaft, and the level was carried another 25 feet southwards. In driving, about 10 inches of clean ore is said to have been met with for a few feet. This was followed downwards, and was found to pinch and make again. An influx of water stopped the work, and the shaft was deepened to 60 feet. The upper level is now worked only when the water interrupts operations at the bottom level.

The 60 feet level has been driven 110 feet north and 40 feet south. For the first few feet north a good shoot of zinc blende was met with. This disappeared rather suddenly in the drive, but before the slide was reached 8 inches of vein-matter appeared, about half of which was galena. This was followed beyond the slide. North of the fault the lode strikes N. 25° E. Then a commencement was made to stope upwards in search of the ore seen on the level above. South of the main shaft a little stoping has been carried on upon a lens of zinc blende which was located in sinking the shaft, but the ore did not prove continuous. The drive was carried southwards on the lode, but without successful results. The lower workings met with a considerable flow of water, which has hampered mining operations to some extent.

About 45 tons of ore have been raised. The first-class galena is reported as assaying 68 per cent. lead and 71 oz. silver per ton.

The best ore is stated to have been obtained north of the slide in the bottom level. On the whole, the bands of galena and blende are more marked in the ore from the lower level, while the two ores were more mixed in the upper workings.

The small size of the vein is a drawback, but to develop this lode sinking will have to be continued and exploration pursued at deeper levels. The tendency of the ore to form separate bands of galena and blende is an advantageous feature, and the silver ratio is encouraging for a lode of this type.

Zeehan-South Comstock, Limited (712-87M, 80 *acres*; 966-93M, 80 *acres*).

This company has the two sections formerly known as Comstock and South Comstock, and operations are now being carried on by the Broken Hill Block 10 Company as optionees. In former days the pyritic-blende galena lodes were worked first for galena, and then for a short time for blende, of which in the South Comstock Mine considerable quantities of pure ore were obtained. The bulk of the ore at this mine, however, will probably be found to consist of a coarse admixture of the two minerals, lending itself to treatment by concentration. At the same time the old workings where the lode was exploited by W. Flaherty showed large quantities of zinc blende, a good deal of which has since been raised and sent away. At present this part of the mine is inaccessible, and at the time of our visit we could see nothing which would enable us to form an opinion of its conditions and prospects. The low tunnel near the Falls has been driven to reach the lode below the South Comstock workings. This lode passes through the sections with a general bearing of N. 20° W., and dipping north-easterly. It has been cut in the low tunnel as an irregular formation of pyrite and blende ore, altogether about 12 feet in width. It is now being driven on north. In the face is dense pyrite, and in the roof behind the end solid blende is exposed. The little galena which was present when the drive was commenced appears to have given out. A couple of yards further on in the tunnel another drive was started, but the orestuff petered out.

On the northern side of the hill is Farr's prospecting adit, started a few months ago. It is being driven north-easterly across black slate to intersect the main lode as it comes north from the open-cut.

The old workings on the northern section are now inaccessible. The lode continued strong, and carrying the same economic minerals—galena and zinc blende in shoots at intervals. A good quantity of galena used to be won, the blende for the most part being left.

The main Comstock shaft was sunk to 100 feet only, and the tributors who worked at different points on the property were handicapped by water.

The galena of this lode has a silver ratio of about 1 oz. to the unit of lead, and some of it has carried appreciable gold. The ore broken gradually showed an increasing admixture of zinc blende, and galena mining became impracticable. The underhand stopes produced mixed ore for several hundred feet.

Other lodes exist on the property. One of these is the East Lode, near the main road, which has been opened upon from the surface, and worked principally for zinc blende. Some galena is associated with the ore. Between this and the main lode is the Comstock East (No. 2) lode, which has been sunk on, and has yielded some blende and high-grade galena.

On our visit we could only walk over the surface of this property, on which so little was being done, and note the indications which were available. It is to be hoped that with the new option the Comstock district will enter upon a period of activity.

Section 3290-M, 39 *acres—J. McDermott.*

This adjoins the Zeehan-South Comstock Company's northern section, and mining has been carried on upon it at intervals for several years.

An adit starting in the south-east corner of A. J. Parker's 39 acres to the north, is being driven in a direction W. 35° S. into the slope of the hill, across nearly vertical slate, to cut a galena-blende formation a few chains from the eastern boundary of 3290. About 50 feet above tunnel-level is a small shaft 20 feet deep, from which 70 feet have been drives north and south, and one stope taken out. The lode is about 3½ feet wide, and strongly pyritic. Its economic mineral is galena, but it also carries zinc blende. It bears N. 15° W. About £300 worth of mineral was sent away about two years ago.

Further west, near the western boundary, is Duncanson's lode, a north-and-south lode worked in very early days. The lode has been cut in an adit driven S. 35° E., and some ore has apparently been taken out. Mostly blende ore has been left on the small pile outside.

Section 1846-M, 39 *acres—A. J. Parker.*

The work on this section is known as Bailey's tribute. It is on McDermott's lode. An adit has been driven south on it for about 60 feet, and near the entrance to this a small shaft was sunk to 120 feet, and the lode was driven on north for 100 feet, and all stoped out to the floor of the adit. This was between two and three years ago. The lode is a pyritic-blende one, with bunches of galena. The latter is said to have a silver ratio of 1 oz. to the unit.

Simpson's Lode.

Thos. Simpson has 40 acres under prospecting licence covering J. Reynolds' lease. A lode is being worked which runs in a N.E.-S.W. direction across the east boundary of Section 2838-M, 20 acres—J. Reynolds. Two hundred and forty feet below the track at the top of the hill an adit has been driven for about 300 feet in a westerly direction (N. 70° W.) to the north Silver Stream lode, and then a drive put in on the lode for 80 feet. From the end of the somewhat serpentine adit the drive south has followed the course of the lode, which towards the end is ore-bearing, and is being carried the full width of the drive (4 feet), dipping to the south-east. There is a good footwall, but no hanging-wall. There is a probability that all the ore has not been taken in the drive, and that it will be necessary to strip the footwall side.

The ore is a bright galena, with an admixture of antimonial ore, and with a little copper and iron pyrites, also blende. The gangue is quartz, with bands of silicified country-rock.

In the north face is a little galena in splashes, but there are no backs in that direction. The former workers must have found some ore in the roof where they left off, as they rose a little in the back of the level. The backs over the present workings are about 30 feet, but the lode has been traced right through south to the foot of the hill along the line of Bottrill's tunnel. It then enters the deep ground of the hill.

There is a parallel lode east of the main one, across the creek, with a channel about 3 feet in width, containing 2 feet of pyrite-bearing slate, with bands of pyrite and galena.

The prospects here are promising for deeper work.

(3)—Contact-Metamorphic Zone.

The group of properties in the contact-metamorphic zone of the Comstock district are the Tenth Legion, the Silver Stream, and the magnetite blende deposit not far from McIvor's, on the road to Trial Harbour. These occurrences embrace both deposits of irregular form as well as lodes more or less defined. The irregular form, however, seems to predominate.

With all these occurrences are associated the peculiar assemblage of minerals (garnet, diopside, tremolite, clinochlore, &c.), which characterise contact-metamorphic deposits. Lime minerals preponderate, and a contact rock consisting of lime-silicate-hornstone or diopside appears to have been formed under the influence of granitic emanations operating on calcareous sediments. Besides the depositions of sulphidic minerals, such as pyrite, chalcopyrite, sphalerite, and galena, there has been the formation of magnetite, a quite characteristic ore for the contact-metamorphic group.

This series of mines has always attracted a certain amount of attention owing to their geologic interest, but up to the present their developments have been limited and unsatisfactory.

Sections 5142-93M, 62 *acres; and* 661-M, 30 *acres*—*W. Thomas.*

This was formerly the Silver Stream section, and afterwards taken up by the Kynance P.A. Mr. Thomas is now working it.

The magnetite lode of the Tenth Legion comes also into this section, but gradually loses its massive character, and is represented by more or less disconnected patches of ironstone.

The main blende galena lode is near the eastern boundary, and courses in a north-easterly direction, parallel with several other lodes to the west of it. It has been worked at different times from two adits, and seems to be a great gossan and clay formation, upwards of half a chain wide, carrying veins of galena and zinc blende, with which copper and iron pyrites, magnetite, and yellow garnet are associated. Large lumps of galena occur loose in the clay and between the heads of gossan. The lower tunnel cuts the intersection of this lode with an east-and-west lode-line, along which a copper pyrites formation of considerable width is developed. Several other galena and blende lodes run through the property in a north-easterly direction.

Tenth Legion Mine on Kynance Section, 720-M, 80 *acres.*

This mine was fully reported on by Mr. G. A. Waller in 1903, and is now idle.

The main feature of the section is the ridge of magnetite which courses across it in a direction N. 60° W. At the east boundary this passes into the old Silver Stream ground; at the west side-line it sinks to the flat, which further west shows laminated hornstone-like outcrops, weathering somewhat like serpentine, but constituting probably some variety of contact-metamorphic rock. It has not yet been examined microscopically. A magnetite outcrop reappears to the north of the flat. West of the marshy flat the granite contact of Mt. Agnew occurs. In the south-eastern part of the swamp there appears to be an occurrence of silicified serpentine, and between this and the granite is the contact-metamorphic rock mentioned above.

The old shaft on the flat is inaccessible. Some rich argentiferous galena is said to have been obtained from the workings, but no signs of any ore are to be seen at surface.

The tunnel at the Tenth Legion Mine driven south into the magnetite ridge was undertaken to see what was beneath the iron outcrop, and to prove the country at its southern boundary. After passing through hardened slates and quartzite the adit intersected bands of impure magnetite, and entered lime silicate or diopside rock. The present face is in magentite silicate rock.

The magnetite outcrop is very massive and pure, and with favourable conditions would be a valuable source of iron ore. The tunnel has apparently passed through a weak part of the iron lode. A break or soft part of the lode is indicated by the configuration of the hill above the drive. Traces of pyrite, blende, and galena have been met with in driving, and although it is improbable that the magnetite will alter in depth, there is nothing to forbid the occurrence of galena or blende as associated minerals. In days to come the iron ore on this property will doubtless be an asset of great value, as there is evidently a considerable quantity of massive magnetite in a pure form, and according to the laboratory tests, containing no titanium and only traces of phosphoric acid.

Section 5637-93M, 80 *acres.*

This is situated about a mile south-west of the Silver Stream, and comprises for the most part a belt of contact-metamorphic silicate hornstones and altered sedimentary rocks, fringing granite on the north and west, and bounded by amphibolitised gabbro on the south-east. The gabbro outcrops on the flat between the Trial Harbour-road and the timbered mountain country of the section.

Towards the centre of the section a wide formation of magnetite and zinc blende has been uncovered by an open-cut. The formation has the irregular form characteristic of many contact-metamorphic deposits and appears to be over a chain wide. Over this width are alternations of blende and magnetite, both often very pure. Hornstone, clinochlore, and mica are associated with the ores.

A pile of good blende had been raised, and in view of the present stimulus being given to blende-mining in the district, it would be worth while to prove the possibilities of this deposit, which from its position above the creek can be done very easily. In the future its iron ore will probably be of value.

The infrequency of occurrence in Tasmania of the contact-metamorphic type of ore-deposit makes a forecast of the behaviour of the lodes in the Comstock district a somewhat delicate task. Important mines, however, situated in similar areas in other parts of the world, to wit, Germany, Hungary, Italy, Russia, Sweden, &c., have been at different times worked successfully. The principal ore of such areas is perhaps magnetite; and the other ores of importance are those of copper, lead, and zinc. The irregularity of the deposits, both in form and occurrence, makes their mining frequently uncertain, and this will most likely be found to apply also to the Comstock deposits.

With the blende-mining now starting at the South Comstock, the zinc bodies at the Silver Stream ought to prove of value. The primary copper and galena ores, even at the shallow level at which mining has been carried on, are in some measure promising in their appearance. Moreover, a good deal of oxidation and leaching has gone on at the levels worked, and this should encourage deeper work, for the secondary processes which have evidently affected the ore have very probably produced a reconcentration of values at the lower limit of the meteoric zone. Irrespective of this there is absolutely no reason for supposing ore-deposition to have been superficial only.

(4)—Miscellaneous.

Mariposa Mine (Sections 2868-M, 10 *acres;* 1235-M, 10 *acres; and* 2867-M, 10 *acres—F. Borley*).

These are three sections which cover part of the areas leased some 20 years ago by the Mariposa, Alameda, Martini, and South Nevada companies.

They are situate about 3 miles north of Argenton, or, as it is now called, Oceana Siding, and are approached by a wooden tramway from the Zeehan-Strahan railway-line, which has been laid down by Messrs. Borley and Statton on the track of the old steel railway or tramway-line.

The country passed through by the tram consists of massively-bedded grits and slates belonging to the middle and upper zones of the Zeehan Silurian.

A pinkish indurated sandstone of the middle zone strikes N. 15° W., and dips steeply to the north-east. It contains indefinite tubular casts similar to those occuring east of the Smelters. They do not penetrate the rock, but lie in the joints or bedding-planes.

Grey, green, and black slates, with strikes varying from north to west occur with encrinital stems, brachiopods, and trilobites, characteristic of the upper zone.

To the south-east are hills apparently composed of the Mt. Zeehan conglomerate series, and it would be interesting and not difficult (with sufficient time) to work out the sequence here.

At the rivulet, just before coming to the mine, limestone country belonging to the lower zone of the Silurian is reached, and the mine is in this rock. It extends into the flat some 5 chains east of the mine, and there junctions with white sandstone. The eastern boundary of the limestone runs down the middle of the flat in a north-westerly direction.

All the work done by Mr. Borley has been on his central section. A lode runs N. 25° W. right through this section; the dip is to the south-west; and the average width is from 8 to 9 feet.

The old main shaft was sunk 140 feet, and an east cross-cut driven from the bottom for 50 feet. At 20 feet the lode was cut into, containing a mixture of milling ore, carbonate of iron, and lime. It was only 4 feet in width, and some doubt was felt as to its being the same lode as that which outcrops at surface, but without any real foundation. The two large excavations into the outcrop show the lode-composition to be galena-bearing gossan, with some carbonate of lead.

An adit has been driven for some 350 feet, but was too shallow to make it worth while continuing it.

About 200 tons of gossan and carbonate ore are on the tip, and this is being sold to the smelters at Zeehan. The average content of the parcels smelted has been 33 per cent. lead and 17 oz. silver per ton. Galena, when in limestone, has usually a low silver content, and this is what may be described as a low-grade; but on the other hand it is not lower than other lodes at Zeehan which are not in limestone country.

The ore is free from zinc, and makes a good flux. Old workings on the same line of lode exist further north.

There has evidently been a good deal of oxidation and leaching, and further exploration by sinking seems desirable. The tramway is a well-graded one, and provides an easy means of getting the ore out.

Austral Valley Flux Quarry.

This is a large ironstone blow, near the road to the Smelters, and situate on the Austral Valley Silver-lead Mining Company's lease—No. 2851.

An excavation has been made into the formation some 25 feet in width, disclosing ironstone, with a few patches of clayey matter. The Smelters have taken intermittent supplies of it for fluxing purposes. Its contents approximately are 50 per cent. iron and manganese, 6 to 8 per cent. silica, and if it is screened it will probably return 5 per cent. lead and 1½ oz. silver. The lead principally affects the manganese. The outcrop is evidently the gossanous part of a metalliferous lode.

VIII.—PROSPECTING.

(1) Prospecting Methods.

Several methods of prospecting have been adopted on the Zeehan field. Some of these are more readily applicable than others, and consequently have been largely followed. The different methods may be enumerated as follows:—(*a*) Prospecting by adit; (*b*) underground prospecting by drives from shafts; (*c*) deep-sinking; (*d*) exploratory boring by diamond-drill, which has only been done in the form of horizontal exploration from underground workings.

(*a*) *Prospecting by Adit.*

This is generally the first thing that is done. A prospecting adit is put in with a view of intersecting the lode about 50 or 60 feet below its surface outcrop. Where the physiography of the country admits of it, it is a ready and cheap mode of learning something of the lode, even in a partial kind of way. That the knowledge thus gained must often be very limited is shown by numerous shallow adits driven into the Zeehan hills, and intersecting only the leached and barren parts of lodes. In many instances the shallow adit is the beginning and the end of exploratory work. It is only when it taps a profitable ore-shoot that a second adit is driven lower down, or shaft-sinking is resorted to. As preliminary work adit-prospecting is economical and useful where the physical features of the lode and the configuration of the country are favourable. The mining industry at Zeehan has derived great benefit from it in the past, and a judicious continuance of it may be recommended.

(*b*) *Underground Prospecting by Drives from Shafts.*

A good many shafts of moderate depth exist on the field, from which exploratory levels have been driven, either below trial adits or in ground where adit workings were not feasible. In addition to these, the shafts of the few deep mines have given access to ground which has been extensively worked. Exploratory drives and crosscuts from such ground have thus become possible, and as it is in this way that the expansion of existing mines is largely effected, the question of what exploring extensions are necessary or advisable is always an important one for each mining company. It has likewise an important bearing on the future of the field, for the horizontal developments in existing mines must for many years be relied upon for a fair proportion of the general output.

This method of prospecting is applicable in the case of such mines as the Zeehan-Montana, Colonel North, Victoria-Zeehan, Mt. Zeehan, and many others which need not be particularised. The precise direction in which exploratory work is to be carried out in any given mine depends upon the geological, structural, and other physical features of its ore-deposits. Appreciative and valuable experience of these has been acquired by mining managers who have been in charge of their respective mines for a sufficiently long period to allow of a close acquaintance with the usual behaviour of their lodes. We beg to acknowledge our indebtedness to managers on the field for much information in this respect. By this means we were placed in a position to rapidly review and consider the facts which could be urged either for or against the conclusions which we were led to form.

An immense amount of horizontal prospecting has been done at the Montana Mine, especially south of the main slide. The intersections of the numerous lodes with the slide are accompanied by ore-deposition on the south or footwall side of the slide, and recently vigorous prospecting has been proceeding to the north of the slide in connection with indications of ore in that direction. The lode which has been picked up on that side may or may not be a continuation of one of those on the south side; it is probably impossible to establish any identity before further work has been carried out. But at any rate the necessity for prospecting on the north side is clearly indicated, even if the lode-fractures do not mutually correspond. The most prominent feature of the mine is that the ore-shoots as a whole are in proximity to the slide, and we know of nothing in the structural characters of the lode-fractures which would indicate a necessary restriction of ore-deposition to one side of the fault. An exploratory crosscut on the north side across the trend of the lines of ore-deposition would prove the existence or otherwise of any northern extensions of lode-channels.

There is ample scope in other mines on the field for this kind of prospecting, and if wisely planned according to the needs of each mine a good deal of it is bound to be fruitful in results.

(c) *Deep Sinking.*

In only two mines on the field have shafts been sunk to any depth worth speaking of. Compared with the depths of some silver-lead mines in other parts of the world the depths attained at Zeehan are insignificant. The Zeehan-Montana No. 1 Mine shaft has been carried down to 800 feet, the Western Mine to 1000 feet, the No. 2 Montana 500 feet, the Silver Spray, 450 feet, Oonah 450 feet, Silver Crown 260 feet. Colonel North 320 feet, Victoria-Zeehan 300 feet, New Mt. Zeehan 140 feet, and others to moderate depths.

The results of the deepest workings, viz., in the Western and Montana Mines, are unsatisfactory, but cannot be accepted as conclusive. There must be deep exploration as well as deep-sinking, and until more extended exploration has taken place no useful opinion can be expressed.

It is asserted in quite an axiomatic way on the field that when carbonate of iron in the lode gangue is followed in depth by pyrite, galena disappears, and is not met with again. When this change occurs managers discourage further sinking. A little reflection, however, will show that this sequence is not altogether a function of depth from surface, because in the pyrite-galena zone both pyrite and galena co-exist at shallow levels. And it is a mistake to suppose that because the gangue changes the ore necessarily disappears. On the contrary, galena is persistent, notwithstanding the variations in the gangue, right through the sideritic and pyritic succession into the magnetite gangue type of the lodes of the contact-metamorphic zone adjoining the granite. The opinion that pyrite and galena are impossible associates springs from partial observation, and is not justified by facts observed over a wider area than any particular mine. Even if they were the fears entertained would be unwarranted, for there is a good deal of overlapping of gangue types on the Zeehan field. The real explanation seems to be that the shoot of ore which has been worked has arrived at its natural termination, and that the usual blank has occurred between it and the next one. How far down this blank extends can only be ascertained by still deeper sinking (or boring). The sideritic gangue type persists down to the lowest level of the Montana Mine, and galena has not gone out entirely. It is impossible for geologists to prophesy at what depth ore may be expected to reappear in the lode-channels. If they could mining would be easy, and would be divested of its speculative character. They are, however, justified in saying that geological considerations not only do not forbid, but involve, the existence of ore at a lower depth, even though the latter may be indeterminable. The necessity of continuous sinking is therefore strongly indicated.

Each mine has its own geological history, and this has to be kept in mind when considering development programmes. For instance, in the Montana Mine the governing factor is the connection of the ore-shoots with the intersections of the slides by the lodes. An obvious scheme would be to explore the lode-channels in the neighbourhood of these intersections. In addition to search north of the slide from existing levels, the company would have to decide whether to continue sinking the present main shaft accompanied by crosscuts of increasing length, or to sink an underlay winze on one of the known lodes, following the latter down in the vicinity of the slide.

The Spray lode, which has been proved on its horizontal extension for 1400 feet, has been developed in depth only to 450 feet below the surface. This development is incommensurate with its history as a productive lode. Rich ore was found in patches in the bottom workings. Though we have not been able to examine these, we see no reason for not proceeding with deeper exploration. Unpayable portions of the lode connected the productive portions in the upper workings, and the same thing probably obtains in depth.

The Argent Flat abounds with intersecting veins carrying good ore, mostly at the intersections, and these occurrences necessarily imply a connection with other deposits in depth. It is reasonable to anticipate that these can be profitably attacked from deep workings.

The Manganese Hill has long been an object of fascination, and admittedly some sort of an ore-deposit must exist below the outcrop; indeed, indications are known at no great depth below surface, but whether or not remunerative ore-shoots occur can only be determined by actual deep trial.

The Oonah Mine owners are meeting with success in the development of their stannite lode, which has been worked down to 436 feet from surface. The lode is strong and satisfactory down to the bottom level, and shows every sign of persistence. The galena lode in this mine was extremely productive in the upper levels, but below 300 feet was poor. The workings on the latter lode are abandoned, and we could not form a proper opinion of the lode in the deeper workings. But as the development of the stannite lode proceeds, it will not be difficult to test the galena lode at a greater depth. Nothing much is known about the cassiterite vein on the Oonah property, but the possibility of the existence of parallel veins (concealed by the surface detritus which clothes the hillside) should induce some exploration. It will be well not to be too sanguine, for very little alluvial tin has been found in the lower ground. We were able only to hear of rumours.

Other points on the field (along the King and Bell line) seem worthy of deep exploration.

(*d*) *Exploratory Boring by the Diamond-drill.*

Views have been expressed locally in favour of schemes for exploring in depth by means of the diamond-drill. It is thought that in this way payable ore-shoots may be located at comparatively little expense, or at any rate with much less expenditure than by shaft-sinking.

There is no doubt the drill possesses a decided advantage in point of speed, and thus the point aimed at is reached in a much shorter time. A single borehole, too, may be put down at a quite trifling cost compared with that of a shaft, though this advantage diminishes in proportion to the number of bores required; and a series of boreholes is in most cases indispensable to enable reliable conclusions to be drawn. In many instances it will be found that objections to the use of the drill in exploring have been based on an unjustifiable reliance placed in the results of a single bore.

The use of the drill generally is strongly applicable to seams of coal, masses of cupriferous pyrite, and large lenses of iron ore, and in certain cases may be advisable in locating quartz reefs which have been disturbed by faulting. Its applicability is, however, more limited in the case of ordinary metalliferous lodes, the ore-shoots of which may exist only at irregular intervals. Not only has the lode to be located, but information respecting the pay-shoot must be obtained. Accordingly, after establishing the existence of the latter, a close series of holes is necessary for an estimate of its values; and even then the information may be misleading.

We have taken into account the general physical features of the Zeehan lodes, and the mode of distribution of their metallic contents, in connection with the advisability of initiating boring programmes, and the conclusion which we have come to is that there are few cases in which diamond-drilling could be advantageously used.

One of these cases is perhaps that of the Oonah Mine. That company is bound to follow its stannite lode down, seeing that it has improved so much in its lower levels, and an opportunity will then be afforded of putting out bores from a deeper level on the stannite lode, to test the galena lode at that depth.

Among cases of dubious advisability might be mentioned lines of bores across the Argent Flat, to prove the nature of lodes at some distance below the surface, and a line of holes to the east of Balstrup's lode, to prove the character of that lode in depth. It would have be close-boring, and the soft nature of the best parts of the ore-shoots might make it difficult to obtain reliable information about what was really passed through. The irregularity of both lodes and shoots forms a continual obstacle to this method of prospecting.

Another somewhat speculative undertaking would be an attempt to prove by means of boring the deeper extensions of the shoots in the Silver Spray lode. The information gained might very easily be quite misleading, owing to the irregularity of the ore-concentrations. The resumption of sinking would seem to be the most suitable method here.

The same argument applies to the Western and Zeehan-Montana Mines. One or two bore-holes are without question inadequate for the interpretation of the features of these lodes in depth. The drill may pass through a solitary bunch of ore (say such a bunch as occurred at Barnett's Mine), or it may intersect a weak part of an otherwise payable shoot; in either case the information is not conclusive.

Considerations such as the above lead us to believe that unless the idea is to spend large sums of money in extensive boring, this method of prospecting will be found to be of restricted applicability within the Zeehan area.

We may here remark that the consideration of working programmes would be much facilitated if managers could be prevailed upon to make their underground plans furnish geological information. It would be easy to make these show changes in the country-rock encountered in driving, faults affecting either lode or country—the extent of the ore-shoots, and the silver ratio in different shoots or in different parts of the same shoot. The plans need not be large and cumbrous, and a separate sheet could be used for the plan of each level. The present practice of not keeping any plans other than those showing simply underground workings intersecting one another on one huge sheet is to our mind objectionable, as it not only exhibits a confusing representation of drives, not always easy to disentangle, but gives no information as to which drives or parts of drives are on lode, on fault-lines, or in country-rock. The sectional plans also do not give any indication of the values of ground stoped.

The varieties of country-rock met with in the Zeehan mines are not at all perplexing in their nature, and are very well appreciated by the mine managers. Uniformity in the names of local rocks could be promoted by the school of mines in the town, if it would draw up a scheme of nomenclature for adoption by the managers.

If these suggestions were carried out, managers themselves would feel the benefit, and official inspections would be made much easier.

(2)—The Extension of the Zeehan Field.

Looking at a chart of the mineral leases of the field, it is at once noticeable that nearly the entire area is divided into mining sections. It may be added that on all of these either lodes or the indications of mineral exist. The field as a whole is covered with a network of lodes, one principal set of these crossing in a north-westerly direction, the other trending north-easterly. Numerous lodes have been worked to a greater or less extent, but numerous other lodes have been merely tapped. Besides these known lodes there cannot be a shadow of a doubt that many others exist still undiscovered. The majority of the unworked lodes on sections still held must have been regarded by mining investors as unpayable and unimportant, and yet out of so many it is almost certain that some if properly worked, would develop into remunerative propositions. The whole area is a mineral one, and it is not reasonable to suppose that the few points where payable mines have been developed are the only ones where ore-concentration has taken place. There are therefore good grounds for infusing more energy into the exploration of existing sections. On many of these work has been abandoned after very perfunctory trial. Sometimes a short adit drive constitutes the whole of the workings or a shaft 50 or 60 feet down has been considered sufficient to disclose the value of the lode. In very few cases has the lode been explored below ground water-level, and in the smaller mines, as a rule, there has been too little cross-cutting. In truth, it is not too much to say that with the exception of a few mines, the entire lode complex of the Zeehan field below water-level is still virgin ground.

East of the field proper the country is geologically similar, and indications are not wanting that mineral lodes are present. Very little has been done in this direction in the way of prospecting. We could not spend much time in exploring this great eastern fringe of Zeehan, but from what we saw of it we judged it extremely likely that future discoveries may make it eventually a distinctly important part of the field.

The presence of ore in a northerly direction is plainly shown by the occurrences on Barnett's and Sligo's sections. There does not appear to be the extraordinary network of lodes which prevails at Zeehan, but not much prospecting has been done in this part of the district, which is, indeed, rather far afield for present conditions of transport.

But one remarkable area of outer Zeehan may be instanced in which there has been a signal absence of prospecting operations, viz., the low country between the Tasmanian tramway and the sea. This country is timbered and devoid of tracks, and is consequently not an easy one for prospectors to get in and out of. It is not surprising that very little is known of it. Yet if any belt can be described as *primâ facie* a geologically favourable one to prospect it is this; for it fringes the southern border of the Heemskirk granite, and embraces probably both the contact-metamorphic and transmetamorphic zones. For 2 or 3 miles up the Little Henty River from its mouth, from Mr. Waller's description, the country contains contact-metamorphic deposits of magnetite, blende, and pyrite, and outside this zone further south one may well expect the normal pyrite-blende and pyrite-galena lode-types which characterise the western part of the Zeehan field.

The southern part of the Zeehan field, too, has not received its fair share of development. It is perhaps natural that the outlying borders of such a large district are comparatively neglected while there is so much that can usefully absorb capital in the heart of the field. In the very centre of the field, as it seems to us, there is much important work still to be done, and which if left undone will leave a large proportion of the area undeveloped and languishing. Large properties, now idle, have resources which are far from being exhausted, but which require capital to explore and ascertain how far they can be made available. Tributing has no doubt done much for Zeehan. It has assisted the mining companies, and benefited those engaged in it. It will, if encouraged, probably continue to render special service in the way of discovering new lodes and working shallow deposits, but something besides tribute work is necessary to the large companies, who are now resting on their oars as it were, and considering what to do with properties which they hold. Nothing serious can be undertaken without fresh expenditure, and this must be realised as the position which has to be faced.

IX.—CONCLUSION.

The conclusion to which we have been led by our examination of the structural geology of the field is that any idea that the Zeehan lodes are superficial phenomena is unwarranted; nor is there any reason for believing that processes of secondary enrichment have had much to do with the shoots of ore which have been worked. The lodes, in our opinion, may be followed down to much greater depths without more than ordinary mining risks; in other words, there must be a continuity of lode-channel between the shoots of ore already exploited and other shoots which, according to all sound theory, must certainly exist at an undefined lower horizon in the lodes.

The large output which has made Zeehan famous has been won from very moderate depths, and, even at those depths, has not exhausted the field. Much still remains to be done in the way of horizontal extensions of exploration on existing sections. It may be that not more than two or three companies will have the courage and funds to continue sinking to any great depth. Even so, if on all sections at present held vigorous prospecting work were in progress, there can be little doubt that some important discoveries would result, and confidence in the field be renewed. The present depressed condition is largely due to two or three of the large companies working out their shoots simultaneously.

But even though renewed exploration at existing levels may result in fresh discoveries, the permanence of the field can only be maintained by continuous sinking, and it is to provide justification for such a policy that we have discussed in this report the facts which appear to us to bear fundamentally on this question.

We take this opportunity of thanking the mine managers and many prominent citizens of Zeehan for valuable information and assistance rendered.

We have also to thank Mr. Judd for the loan of photographic blocks from his negatives of Zeehan, reproduced in this report.

We are likewise indebted to the Rev. H. H. Anderson, M.A., of Zeehan, who after many years' search in the Silurian strata of the district generously donated a collection of fossils to the Geological Survey. Mr. Robt. Etheridge, Curator of the Australian Museum, Sydney, who has so often assisted in the determination of our Tasmanian

fossils, examined this collection, and other specimens which we submitted to him, and he has given us his identifications, of which we have made use in this report. Mr. W. S. Dun, Government Palæontologist for New South Wales, has also looked over our collections, and given us the benefit of his experience.

W. H. TWELVETREES,
Government Geologist.

L. KEITH WARD, B.A., B.E.,
Assistant Government Geologist.

Launceston, 3rd May, 1910.

GEOLOGICAL SURVEY OF TASMANIA.

List of Publications.

Bulletin	No. 1.—The Mangana Goldfield, by W. H. Twelvetrees	1907
,,	No. 2.—The Mathinna Goldfield, Part III., by W. H. Twelvetrees	1907
,,	No. 3.—The Mount Farrell Mining Field, by L. Keith Ward, B.A., B.E.	1908
,,	No. 4.—The Lisle Goldfield, by W. H. Twelvetrees	1908
,,	No. 5.—Gunn's Plains, Alma, and other Mining Fields, North-West Coast, by W. H. Twelvetrees ...	1909
,,	No. 6.—The Tin Field of North Dundas, by L. Keith Ward, B.A., B.E. ...	1909
,,	No. 7.—Geological Examination of the Zeehan Field: Preliminary Statement by W. H. Twelvetrees and L. Keith Ward, B.A., B.E.	1909

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